monopoles?

KOLB: If I think about it, it is only after doing the basic science.

HOWE: Is it necessarily the basic researcher's responsibility to come UP with the utility of it? There are, perhaps. other people who are more interested in the engineering side, so they take the proton-monopole catalysis concept that Rocky mentioned and say. "Well, let's develop starship drives: let's design power reactors!"

SCIENCE: *Rocky, how do you choose your research projects? You 've said how you don 't choose them.*

KOLB: I don't know, actually, I don't know what I am going to be doing tomorrow or when I go back to my office. I read the literature and see what other people are doing. This communication is very important. I follow the direction the work is going.

HYMAN: You may recognize a problem as being important, but in the end the choice is subjective. A question gets under your skin, and you can't let loose until you understand it. That's the driving force behind science—the need to understand. As far as Rocky's responsibility to the Laboratory, that has become clear as he's talked, His obligation is to push back the frontiers of basic science—that's his job description. At the same time every scientist has a responsibility to the overall health of the Lab. Whenever you discover something that could be applied in a programmatic effort, you go down the hall, knock on doors, and make sure the right people know about what you have done.

KOLB: When I first read about Callan and Rubakov's work on monopole-catalyzed proton decay, I was at Aspen, and I said, "Well, I have to get back to Los Alamos and tell people about this." but then Stirling and I decided it couldn't work, so I didn't go knocking on doors.

WHEATLEY: Coming back to the missions of the Laboratory, I understand why we should be doing some basic science and much fundamental technology, that is. research on problems whose ultimate objectives are fully seen. However, my own view concerning applied work and hardware is that if you have a particular, well-defined job to do, the private sector would probably do it better.

HECKER: I would disagree, John. The weapons mission is a specific job, and we have done it very well.

WHEATLEY: The weapons case is rather special because of the national security problem. Suppose that you took the secrecy requirements away.

BAKER: In fact, private industry does secret work, builds all the components. We provide the overall science and technology. I don't think secrecy is the defining factor, The national laboratories are most effective doing both the theory and the design development of jobs that are high risk and from which an industry couldn't expect a profit in a short term. Fusion is another example.

HYMAN: Our exceptional facilities also give us an edge over industry. The two thousand scientists at Los Alamos comprise a pool

Sig Hecker on Materials Science

Materials are the *sine qua non* for new technology. At Los Alamos we have been in the business of processing new materials for technological needs from the very beginning. Now materials processing is becoming more sophisticated as we learn to exploit our understanding of materials on an atomic level. Our work on rapid solidification and ceramic processing exemplifies this trend.

So-called rapid-solidification-rate materials are made by cooling the liquid state very rapidly, on the order of a million degrees per second. The rapid solidification avoids equilibrium decomposition and consequently affords the opportunity to create materials with new and novel structures, For example, if you smash a liquid metal between an anvil and hammer or spin it against a cooled, rotating wheel, you can create a metallic glass, that is, an amorphous metal rather than a metal with the normal polycrystalline structure. Properties of metals depend critically on their crystal structure, or, more specifically, on the defects in the crystal structure. By creating an amorphous metal, we eliminate grain boundaries, which contain many defects and are therefore places where corrosion begins. Consequently, these metallic glasses have good corrosion resistance as well as high strength. Our rapid solidification work at Los Alamos has been applied mostly to processing actinides.

Our work in ceramics processing is aimed at a new class of structural materials for high-temperature environments, such as those involved in fuel processing and power generation. For example, a ceramic turbine might be used to achieve higher operating temperatures and higher efficiencies.

State-of-the-art work is being done in two areas: processing of dense ceramics without densification additives and growth of ceramic whiskers, The ceramics of greatest interest to us, silicon carbide and silicon nitride, must be made at relatively low temperatures to avoid decomposition. A densification additive forms a glass phase between the powder particles and essentially glues the particles together. Unfortunately, during high-temperature service, in a turbine for example, the glue turns glassy and the ceramic loses strength. To eliminate the need for an additive, we have developed a technique for making an extremely fine, extremely reactive powder that shows great promise of densifying at low temperatures. We form the fine powder particles, which have diameters on the order of hundreds of angstroms, by a plasma-assisted chemical vapor-deposition process. In this process the constituents, such as silicon and carbon, are carried by appropriate gases and are reacted in a hot argon plasma. We are also using the Laboratory's expertise in shock loading to activate ceramic powder containing larger diameter particles. The idea is to produce a large concentration of defects on the surface of the particles before attempting to consolidate them.

Ceramic whiskers, a field in which we are the world leader, are long, single-crystal fibers of, for example silicon carbide or silicon nitride, with diameters that vary from less than a micron to maybe ten microns. These single crystals are grown by a process called the vapor-liquid-solid process. They are essentially defect free and have enormous strengths, from ten to fifty times that of structural steel. We are now trying to incorporate the whiskers into a composite material-a glass matrix, a ceramic matrix, or a glass-ceramic composite—to make high-temperature materials. Essentially, we are using processing science to control the strength and the ductility of materials on a microstructural level.

Another area that is not new, but extremely fascinating, is the actinides. In the last few years a marriage of condensed-matter physics, chemistry, and metallurgy has helped us to understand the intriguing electronic and magnetic properties of these elements and, in particular, how they determine the macroscopic properties of plutonium, uranium, and americium. For plutonium, especially, the only way to understand it is to understand the role of its bonding *f* electrons. For example, because the *f*-electron wave functions possess odd symmetry, bonding of these electrons favors unusual crystal structures with low symmetry. People in academic circles are now becoming very interested in the actinides because they offer new physics. ■

of knowledge found in only a very few places. Also we have five Crays and a complete set of shops.

WHEATLEY: We do have a complete set of shops, but it costs fifty-five dollars an hour to use them.

HYMAN: But they are at our disposal.

COLGATE: Just for a moment let me reduce the main missions and the main capability of this Laboratory to plain terms. Suppose we didn't have a Laboratory. Why would Congress, the politicians, want to start one? The only reason would be because they were scared: scared of losing the country—that's our national security mission—or scared of losing our way of life and our power—that's the energy mission. Fear for the future motivates the existence of this Laboratory. Politicians would never fund science from purely altruistic motives, and purely educational business would be in the universities where it belongs. But how do you make sure that a new idea doesn't come up to bite you from the rear, as Sputnik did? You have the most brilliant people around to think up all the new ideas that are possible before someone else thinks of them. So the basic capability of this Laboratory is its brilliant individual scientists. If someone wants you to come to the Laboratory, why do you accept? Because people here are doing the most exciting research in your field, and because you believe in your own ability,

ROCKWOOD: There's something I worry about, and I'd like to mention it here. At moments of international crisis, programs for the national laboratories are easily defined. But during periods of uncertainty about the future, and especially during periods of economic stress, the selection of programs is not so simply made. One of the strengths of Lo's Alamos internally is its great freedom of thought—freedom to disagree, to discuss openly with management the pros and cons of particular technical endeavors. It makes us stronger to have had these discussions and to look at all sides of a problem before going into it. But we should speak with only one voice to the external world. We don't need two, three, half a dozen people showing up in the same office in Washington, each with a different opinion as to which major programs the Laboratory should be pursuing.

SCIENCE: *While you more or less agree that the development of high technology for national security is the Los Alamos mission, the specific emphases and manner of carrying it out remain open to discussion. Perhaps we should turn now to some of the specific areas of research and development that are clearly important. Carson Mark has commented that many of the problems in technology development are materials problems. Sig, would you tell us what is being done at Los A lames in this area?*

HECKER: Our materials science effort demonstrates the exciting and productive relationship that exists between theory and experiment. It is one of the beauties of this Laboratory that metallurgists, physicists, and chemists work side by side. Our main interest in materials