letters

Once the simpler inorganic crystal structures had been determined, the methodology of crystal structure analysis became very difficult, especially when applied to organic molecules. This was because of the phase problem. While this gave the research considerable intellectual appeal—like playing chess against Nature—it made it very time consuming and often tedious. Nevertheless some scientists with special combinations of curiosity, insight and determination persisted, such as Max F. Perutz (Chemistry, 1962), Dorthy M. C. Hodgkin (Chemistry, 1964), Odd Hassel (Chemistry, 1969), William N. Lipscomb Jr (Chemistry, 1976) and Monteith Robertson. Although the last named was not awarded a Nobel Prize, he was elected president of the Chemical Society (UK) in recognition of his crystallographic contributions to chemistry. Assisted by the rapid development of computer technology, but using methods developed for small molecules by Arthur L. Patterson (a physicist) and Robertson (a chemist) in the 1930s, Perutz and John C. Kendrew (Chemistry, 1962) demonstrated the use of x-ray crystallography to determine the atomic structures of very large molecules, namely proteins. Physicist Aaron Klug (Chemistry, 1982) extended this work to methods for the structure analysis of even larger molecules, the viruses.

With the recognition of the importance of molecular shape, or conformation, by Hassel and Derek H. R. Barton (Chemistry, 1969), x-ray crystallography began having a tremendous impact on chemistry. Crystallography was able to play such a major role in chemistry because of the invention of a mathematical method, based on probability theory, for solving the phase problem. It was for this invention that Hauptman, a mathematician, and Karle, a chemist, were awarded the Nobel Prize in Chemistry.

Interdisciplinary transfer or collaboration between the major disciplines in science is a theme that runs through these discoveries. Yet the increasing sophistication of the sciences has led to a segregation in university education that drops the curtain between them at increasingly earlier stages. It is rare that a graduate physicist can, or wishes to, understand the language of even an undergraduate chemistry course. A solid-state physicist can be surprised to learn that proteins and viruses can be crystals. Similarly the mathematical logic of physics undergraduate courses is a mystery to most biochemistry and biology students.

Crystallography is fortunate in that through the congresses of its International Union, the 14th of which will meet next year in Perth, Australia, and its publications, it serves as a meeting place for the sciences. At these congresses, the physical, chemical and biological properties of substances are related to their atomic structures by discussions among chemists, crystallographers, mathematicians, mineralogists, solid-state physicists and materials scientists.

Perhaps that is part of the answer to the question.

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10/86 *University of Pittsburgh*

The 'social purpose' of SSC

After reading the barrage of letters (April, page 11) responding to Leon Lederman's reply to Rustum Roy's letter (September 1985, page 9), I feel compelled to add my views on the need for SSC. The dominant theme in Roy's view is that high-energy physics is not basic science. In his view, basic science is "that which is closest to human needs and which holds out hopes for the greatest effect on the greatest number of the nation's citizenry." This broad statement may be applied to agricultural engineering as well as to religion. Lederman did not address this matter directly in his response. I hope to do so here.

First, as a graduate student in high-energy physics, I am insulted to be told that I am drawn to the field because it is the "most glamorous, most high-powered, most prestigious, most arcane, [and] the smallest." My reason is the one that draws so many people to science, and physics in particular, but one that few people articulate: How did we, and the rest of the universe, get here? What makes us, and the rest of the universe, tick?

Such questions are basic to human nature, and are the basis of both religion and science. Recent discoveries (the W particles and the Z), and theoretical concepts such as QCD and supersymmetry, to name only a few, lead me to believe that such general questions may be answered by the human race in the future. The fields that currently ask such questions are high-energy physics, cosmology and astrophysics. But, to put words into Roy's mouth, what would be the social purpose of this knowledge? I ask him, what was the social benefit of the

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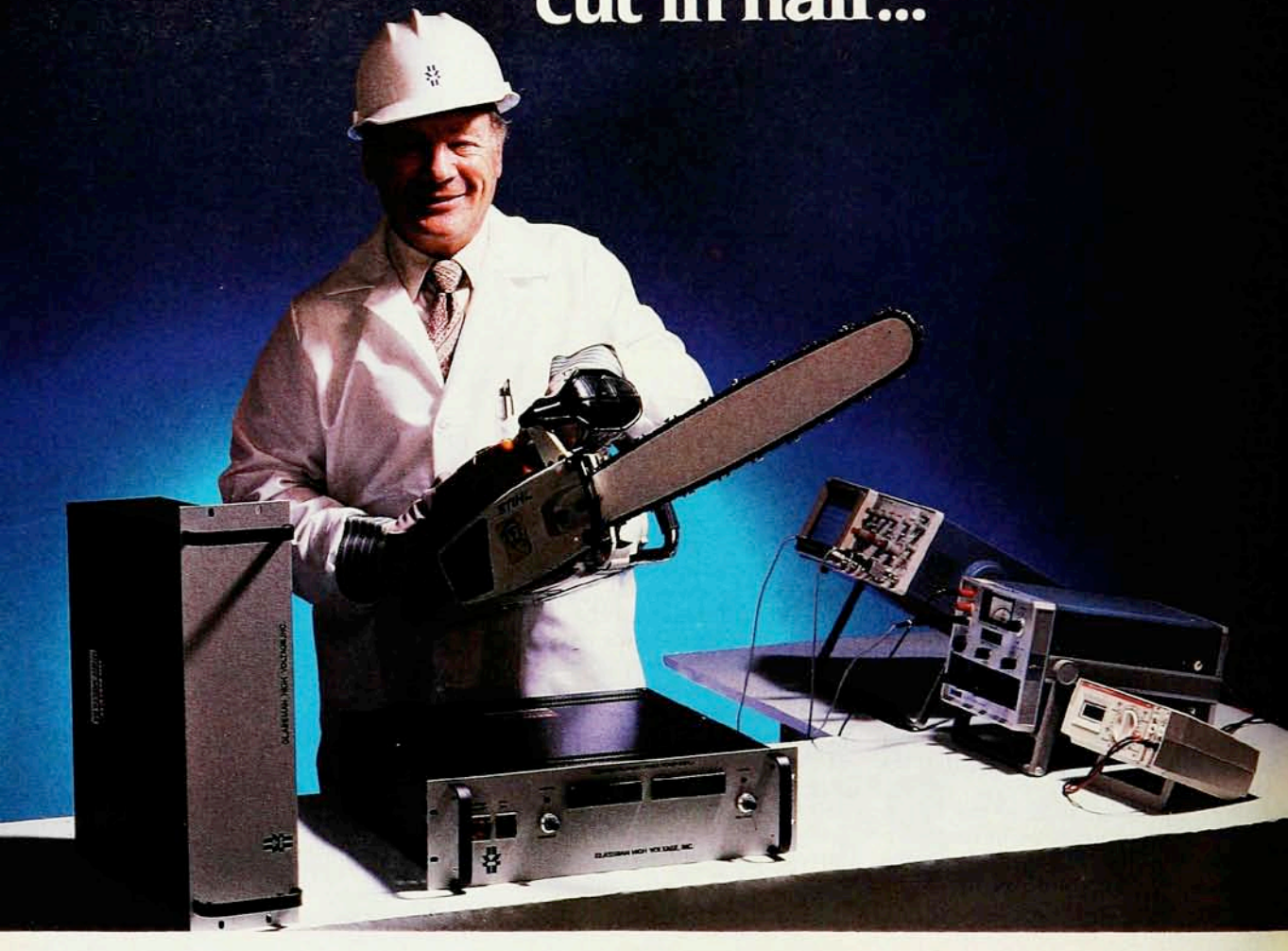

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overthrow of the Ptolemaic view of the universe? For Copernicus's society, the effect was negative, in the eyes of the church at least, but our society has assimilated the Copernican view into its everyday life. Copernicus could perhaps have been of more use to his society had he grown vegetables or designed siege engines. Perhaps a more pertinent question is whether we, as a society, need to know how we came to be here. This is the ingredient that I feel is missing from the SSC debate.

Finally, I wish Roy would define "social purpose." Who would decide whether high-energy physics or materials science has more of it? Does Roy speak of US society, Western society or the society of all people on the planet? Maybe our society does not need smoother surfaces so our engines run more efficiently. Perhaps instead our society needs a coherent picture of its place in the universe. My view is that there is at present too much emphasis on technology and short-range goals, at least in Western society. Most of our societal problems are political and not technological. Have nmr scanners or hybrid grains prolonged the life expectancy of those starving in Africa? Will an orbiting Maginot Line prevent nuclear-armed cruise missiles from striking the US? Will high-speed computers solve unemployment problems? I think not. If anything may be said, it is that technological "solutions" to political problems exacerbate those problems. There is no technological fix. What is needed is a basic restructuring of society's view of itself. I see the international cooperation in high-energy physics and other fields as a tentative model for a world society.

There are fundamental questions that physicists have pondered over many decades. These are problems that a physicist may solve but a politician cannot. The answers may or may not have a profound effect on tomorrow's society. In a matter of decades, without SSC, high-energy physics will become technology. With SSC, it will be as exciting as I find it now.

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ROY REPLIES: Bruce Baller and I share many viewpoints, especially regarding the importance of political and economic decisions compared with technical ones, and the philosophical and religious import of particle physics. We share a desire to find out "what makes us . . . tick" and "how did we . . . get here." I am sure that a graduate student of Baller's sensitivity will be aware that for the vast majority of citizens those two questions are immensely more relevant insofar as they are concerned with the here and now: their families, neighborhood, jobs, next week, next year. Some of us are concerned with the first femtosecond of an event some 20×10^9 years ago. I teach cosmochemistry to 50 graduate students every fall and recall for them that during the 30 years I have taught the course the certainties of science have moved the age of the universe from 3.25 billion to about 20 billion years.

Baller and many others might misunderstand my stance on SSC and similar machines. I have no quarrel with their being built. It is only against the use of public funds for that purpose, at this juncture of the collapse of the American economy, that I argue. I suggest that Baller, who is used to astronomical numbers, acquaint himself with the size of the US deficit, the US debt, the annual carrying charges on just President Reagan's debt, the projected foreign debtor status of the US in 1990, and the extent of Japanese financing of the US debt. Then he could perhaps explain to the taxpayer in the Corn Belt or the ghetto why he feels he—and not some "welfare queen"—should be financed out of the public purse to pursue his—and my own—essentially religious pursuit. Fred Hoyle, editorializing in this very magazine (April 1968, page 149) said we should "recognize ourselves for what we are—the priests of a not very popular religion." Baller seems to agree, as do I. In a secular state couldn't some enlightened taxpayer say one day, "Try meditation instead, or get private financing."

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SDI, its critics and theirs

One of the most important considerations in deciding whether it is appropriate to fund a particular piece of research is its timeliness. If the research does not grow in a suitable way from existing knowledge it is not interesting nor valuable.

When Secretary of Defense Caspar Weinberger replies to technical criticism of the Star Wars program by saying, "They said we couldn't fly" or "They said we could never get to the Moon," he is being deliberately disingenuous. If in the year 1800 the United States had begun to devote a large fraction of its disposable income to building a heavier-than-air flying machine, it seems to me a fair assumption