knowledge is not enough, donors could be offered a touch of immortality in the form of brass plaques announcing, "this magnet contributed by Joe Jones."

If this fails, Federal funding could be obtained by another stratagem. Add another bending magnet directing the primary beam upward and claim that it could be used to destroy incoming enemy warheads. This idea would then be no more farfetched and no more expensive than some of the proposals currently under investigation for the "Star Wars" Strategic Defense Initiative.

ROBERT J. YAES
10/85 *Brooklyn, New York*

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I read with interest Sheldon L. Glashow's and Leon M. Lederman's account of SSC and its significance, in the March issue of PHYSICS TODAY (page 28). For me, it is hard to understand how in modern times, in which all religious dogma is held to be but human invention that one is free to accept or reject, physicists can still believe that their equations are the ones that rule all causality in the cosmos. Must we still hold that our mind is at the center of the universe?

P. J. VAN HEERDEN
4/85 *Woodinville, Washington*

Funding big science

I am writing to comment about the recent letter by Rustum Roy (September, page 9) titled "Funding big science." Even though some of his concerns have been addressed by others, I feel that a few additional comments are appropriate.

Roy argues that because big-science facilities have become so expensive, they are not worth their cost. He believes that all science should be "brought into a new balance" based on the criterion of eventual social utility. I would like first to take issue with the distinction between big and small science based on presumed funding-level differences. A close examination of science-funding needs demonstrates that further progress in all branches of science and technology depends on up-to-date instrumentation, which is becoming ever more expensive. In many respects we are all in the same boat.

The above point has been amply documented in the March 1985 issue of PHYSICS TODAY. The articles on major facilities show that not only high-energy physicists but also nuclear scientists, plasma physicists, biologists, chemists, materials scientists, medical scientists and many others rely in their research on ever larger and more expensive facilities. The article written by Daniel Kleppner (March, page 79) on behalf of "small-scale-research" practioners further supports this viewpoint. After enumerating some typical prices for instruments needed in such areas of research Kleppner concludes: "Setting up a typical small laboratory can cost anywhere from a few hundred thousand to over a million dollars." Regarding operating costs he writes, "an active university research group can require $200–$400 thousand per year; many groups need much more." Earlier he notes the critical shortage of instrumentation in university laboratories and quotes estimates of a "total need [of] over $1 billion." These are the sad facts of contemporary scientific research.

With regard to SSC, we note that while it is indeed a very expensive instrument, it is also the only major facility being requested by the high-energy community and its cost can be legitimately written off over a 10-year planning and construction period and 15–20 years of exploitation. Viewed in that context, it is not clear that there is a significantly disparity between the funds being requested by the high-energy community and those required by several other scientific disciplines.

But there is a more important issue, namely whether the support of a given science should be predicated on its ability to demonstrate contributions to "stable employment, ···prosperous new and old industries and··· a cleaner environment." I have several difficulties with such a criterion.

There would be serious consequences were we to abandon our quest for understanding the world around us independent of the immediate practical application that such knowledge might give us. For several millenia this intellectual curiosity and the ability to pass the acquired knowledge to future generations have distinguished mankind from other inhabitants of our planet. Are we going to abandon it now, at a time when we have made unprecedented progress in raising the level of well-being of all mankind? Are we now going to be interested solely in satisfying our material desires?

Even if we answer yes to those questions, a practical difficulty remains. What is the algorithm that will determine which research is most likely to further our technological know-how? What value do we put in the algorithm for the stimulation of young minds and inducing more students to go into science, mathematics or engineering? Ernest Rutherford, six years before the discovery of nuclear fission, declared, "Whoever says that nuclear energy cna be practically used speaks moonshine." And thus, I would argue,

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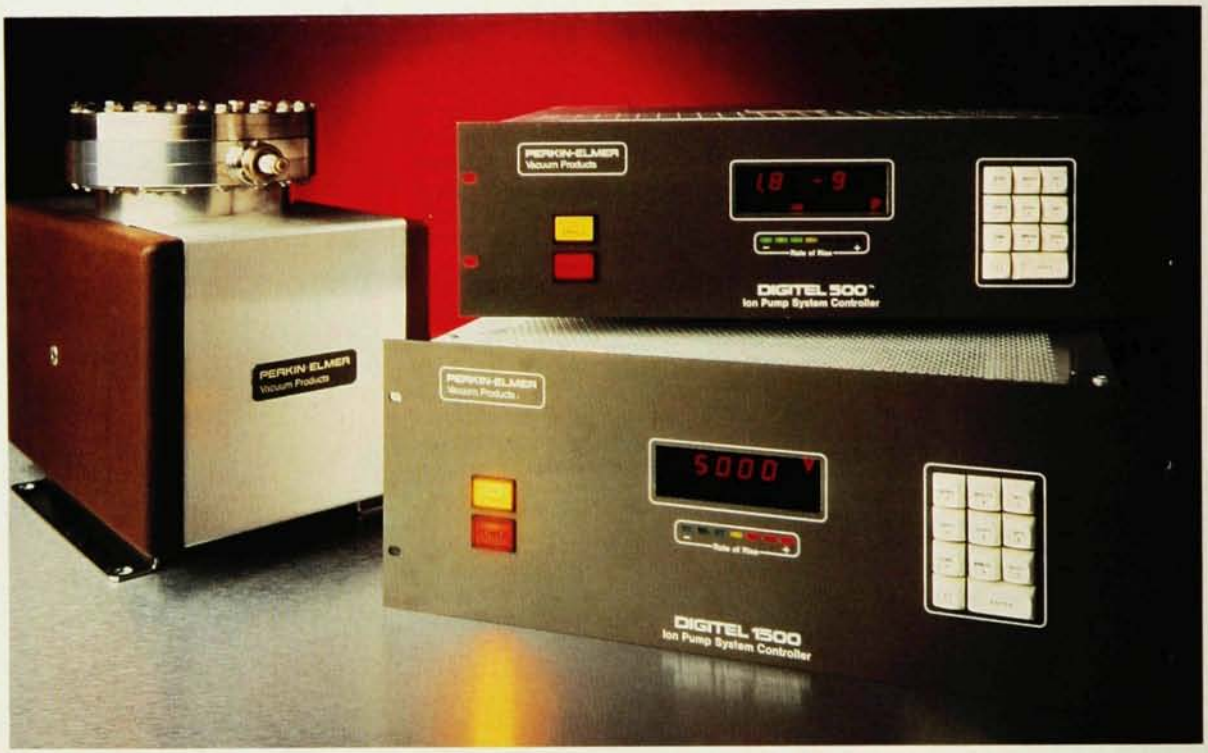

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it is highly unlikely that government officials or a group of scientists would be capable of forecasting the future benefits of a given line of research.

But the issue is even more serious. Just because a science furthers an old technology or generates a new one, it does not necessarily mean that this technology will improve the quality of life. The overall balance may well be either positive or negative. Would a policy based on such utilitarian criterion have supported research in nuclear physics? Who would have decided if the threat of potential destruction by a nuclear holocaust outweighs the benefits of nuclear medicine? Isn't such a policy just one step away from outright direct control of science by governmental authorities? Don't we run the risk of repeating such misfortunes as the condemnation of Galileo's research by church authorities and the imposition of strictures by Nazi Germany against teaching the theory of relativity?

I strongly disagree with Roy's statements about the supremacy of technology over basic sciences. In today's world, healthy technology is certainly essential to scientific progress but it does not guarantee it. A general climate recognizing the need for free and diverse pursuit of fundamental knowledge fis an even more essential factor.

I might point out the statement by Mikhail Gorbachev in his 11 June speech to the Central Committee of the Soviet Communist Party, outlining the strategy for catching up with the US technological lead: "The development of pure science must be given priority. It is precisely this science that generates ideas, effects breakthroughs in new fields and makes it possible to obtain new levels of efficiency. Pure research is a matter that is too crucial to accept weaknesses."

As a high-energy physicist deeply committed to SSC, I nevertheless do not want us to proceed with its construction if it will damage other scientific subfields. But I do not believe that we have to settle for a choice of supporting either SSC or other sciences. Basic research is still greatly underfunded in this country. We should all strive together to increase public awareness of its benefits. We need to convince the public and the government that even in these times of tight budgets we must support science or seriously endanger our future.

Our concern with other sciences is due only partly to appreciation of the symbiotic relationship among all the scientific disciplines. SSC could not go forward today without the previous advances in superconductivity achieved by the materials scientists, just as research in biology, chemistry and condensed matter would be worse off without synchrotron-radiation sources, a byproduct of high-energy-physics research. But more importantly, as scientists and human beings, we are filled with awe, wonder and excitement by discoveries in other fields just as in our own. I cannot imagine that high-energy physics could thrive without a broad commitment by our society to the support of all good science. We need to work together to convince the decision makers that broad support for science in general is crucial for our economic and cultural future.

STANLEY WOJCICKI
SSC Central Design Group
11/85 *Lawrence Berkeley Laboratory*

RUSTUM ROY REPLIES: Stanley Wojcicki's letter is—I say this without any effort at sarcasm—quite touching in its evident goodwill and simultaneous naiveté. I will refer to only two examples. He asks, "Isn't such a policy just one step away from outright direct control of science by governmental authorities?" I wonder what he thinks "controls" science now. Government bureaucrats and elected officials absolutely control the big picture of about half of all US science via the budget-allocation process. The details they leave to the scientists. Jacques Cousteau (*Calypso Log*, September 1985) notes the elementary fact that "the public owns science." But, he writes, they have given up their democratic right to direct their own property. I am sure the SSC community does not advocate taxation without representation. Very simply put, shouldn't we have a national debate presenting the very different ways of spending $6 billion that the physicists, biologists, chemists and materials scientists can come up with? I would be happy to leave the outcome of funding SSC to such a referendum.

Wojcicki and your other readers should not misunderstand my position. I advocate the minimization (not elimination) of Federal control of and, nationally, support of scientific research having no obvious utilitarian purpose—what one might call genuinely atelistic research. The private sector is the appropriate place for at least a substantial portion of the support for the great cultural themes of any civilization—in which I include not only SSC, but also the equally noble and spiritually essential human ventures of music, art and the humanities. I am sure most physicists agree, in principle. But when it comes to practice at least some revert to platitudes such as Lederman's wonderful device of using "virtual" dollars for SSC. I will support a $20-billion budget in virtual dollars for a virtual SSC. Wojcicki writes, with a

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letters

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ring of genuine sincerity, "I nevertheless do not want us to proceed with its construction if it will damage other scientific subfields." But damage to other fields is done much more by omission than by commission. Take but one example: May one ask what statement APS issued, or what letters Wojcicki wrote to his Congressman, urging the restoration of the fire- and building-research programs at the National Bureau of Standards? The Reagan Administration has tried for 5 years to eliminate a few million dollars each for the only coherent research in these critical fields. I submit that the good science per dollar judged by the average scientist or engineer in the US in those programs was a factor 10^n higher than that in SSC (where n is not too small an integer). Did those who cared about "all science" even hear of the issue?

Wojcicki's last sentence, however, shows that he has missed the entire point of the debate. Some of us who read the literature, study the issues and work in science policy assert (see D. Shapley, R. Roy, *Lost at the Frontier*, ISI Press, 1958) and have demonstrated that the particular grossly unbalanced kind of "broad support for science in general" that the US has been pursuing is destroying our economic and technological base. Perhaps Wojcicki can read up on some of the literature and give us some data to support such wild—albeit common—misjudgements.

RUSTUM ROY
Pennsylvania State University
12/85 *University Park, Pennsylvania*

Strategic Defense Initiative

Thanks for your compilation of views on SDI from academia (July, page 55). I have two persistent thoughts about ballistic-missile defense that completely disillusion me about its ultimate efficacy.

First, any country that has a ballistic-missile-defense system will worry continually that its adversary may find a way to penetrate it. This concern will lead the possessor nation to retain a strong nuclear offense and to seek ways to assure that its weapons can penetrate the adversary's defense. This prospect contains the seeds of the largest, most futile and most wasteful technological race in history. This race will provide an endless gravy train for contract-hungry scientists, engineers and corporations without offering any hope of rendering nuclear weapons "impotent" and "obsolete," as President Reagan fondly hopes.

Second, I see no way of ensuring that "suitcase bombs" cannot be used to penetrate a missile defense at a small fraction of the cost of the defense. It is ironic that the continual testing of nuclear weapons to make them smaller, lighter and more powerful is providing some of the critical wherewithal to implement the clandestine deployment of suitcase bombs.

The greed that will spawn millions of SDI-research grants without the recipients ever questioning whether our country really wants a defense also inhabits the psyches of individuals who would gladly help hide and deliver suitcase bombs in their own country if the price was right.

How long will it take the Administration to stop promising to share ballistic-missile-defense technology with our adversaries? Disclosing the details of a defense plan is the surest way to aid an adversary to penetrate that defense. All of the talk about classification of SDI research and about the Soviet antenna at Krasnoyarsk as a probable violation of SALT 1 suggests official US ambivalence about sharing US ballistic-missile-defense technology.

For the protection of our citizens, I advocate that an independent adversarial agency funded equally with SDI be established to study reasons for not proceeding with SDI and ballistic-missile defense. I believe the reasons include arms-control and foreign-policy considerations as well as technical and economic ones. The equal funding I suggest would be at a considerably lower level than current SDI funding—perhaps $0.5 billion a year for each program for three years.

Now is the time to ask, "Should the United States work on ballistic-missile defense, even if it can?"

GORDON W. MCCLURE
7/85 *Albuquerque, New Mexico*

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We space scientists have read a lot about the Strategic Defense Initiative, which we call the Star Wars Fantasy, including a four-page nonpartisan summary in PHYSICS TODAY (July, page 55). In the spirit of giving SDI a fair break, I'd like James A. Ionson's response to the following questions:

▶ Will moving military activities (SDI) into space help or hinder space exploration over the next few decades, when we hope to establish an international space station and lunar base in preparation for manned missions to Mars?

▶ Doesn't history show that a new offense can always overcome a defense—as in the case of the Maginot Line in World War II?

▶ Assuming that SDI can develop an effective defense against ICBMs (a violation of the ABM Treaty), won't the offense go under the defensive barrier