

ROUNDTABLE: SCIENCE UNDER STRESS

Physics in the US is beset by a paradox: It is more vital and productive than ever, with more people and wider horizons in the field, yet its practitioners are down in the dumps. Just when physicists ought to be thrilled and tantalized by the unlimited challenges, they are devoting more effort to getting funds to do their work. PHYSICS TODAY assembled eight prominent scientists to discuss the malaise that grips physics and physicists.

Roundtable participants

Erich Bloch, former vice president of IBM and former director of the National Science Foundation; now Distinguished Fellow of the White House Council on Competitiveness

George E. Brown Jr., member of Congress from California and chairman of the House Committee on Science, Space and Technology

George H. Heilmeier, former director of the Defense Advanced Research Projects Agency and former senior vice president and chief technical officer of Texas Instruments; now president and CEO of Bellcore

Daniel Kleppner, Lester Wolfe Professor of Physics at MIT

Leon M. Lederman, former director of Fermilab; president of the American Association for the Advancement of Science; professor of physics at the University of Chicago

Homer A. Neal, former provost at the State University of New York at Stony Brook and former member of the National Science Board; now professor of physics and department chairman at the University of Michigan

Roland W. Schmitt, former vice president for research at General Electric and former chairman of the National Science Board; now president of Rensselaer Polytechnic Institute in Troy, New York

Alvin W. Trivelpiece, former director of the Department of Energy's Office of Energy Research; now director of the Oak Ridge National Laboratory and vice president of Martin Marietta Energy Systems

Gloria B. Lubkin, editor, PHYSICS TODAY

Irwin Goodwin, senior associate editor, PHYSICS TODAY

Lubkin: Because the sponsor of this discussion is PHYSICS TODAY, we would like to concentrate on physics. But you needn't limit yourselves to physics, since many of the issues obviously transcend our own field. Many physicists—and scientists in general—have been complaining, even before the country fell into economic recession, that funding for research is inadequate, that their subfield is hurting everywhere, at universities, national laboratories and industrial companies. With the issue of funding so pervasive, I'd like to start by asking whether budgets for physics research are considered adequate today and whether physicists are realistic about this, given the state of the economy and the demands on the government.

Kleppner: There are obvious problems in the health of science in the United States today, but they are related only in part to funding. The problems are also related to pre-college education and related to the changing role of the universities. The problems one sees throughout the science enterprise reflect the wider national scene. It is not only science that is under stress; the entire nation is under stress. I believe there is a funding shortage in physics and that it is serious. But it is difficult to address that problem without addressing these broader national issues.

Goodwin: Can you speak to the other issues that are affecting physics?

Kleppner: Let's look at some of the nation's concerns and what we're doing about them. To a large extent, we're dealing with problems of the past. For instance, environmental contamination at the nuclear weapons complex is a problem inherited from the past. The bills have come due for our neglect of safety, health and environmental protection while we were preoccupied with producing nuclear warheads throughout the cold war. Then there is the savings and loan scandal—another problem of the past that we are paying for now. We are also trying to deal with the problems of our public schools, with an increasing homeless population, with deteriorating roads and



Science policy experts meet in Washington, DC, with **PHYSICS TODAY** editors. Seated around table, clockwise from left: Leon Lederman, Erich Bloch, George Brown (partly hidden), Homer Neal, Gloria Lubkin, Irwin Goodwin, Roland Schmitt (hidden), Daniel Kleppner, Alvin Trivelpiece and George Heilmeier.

bridges, with a rising rate of infant mortality. I could go on. What I miss in our country today is a sense of the future. We seem to be dealing with emergencies and paying for the years of neglect. In contrast, science looks to the future. If this country is to have a future, science must play an important role. But I do not see the nation seriously concerned with its future.

Goodwin: Your comments are extremely apprehensive. Still, whenever President Bush speaks of science he refers to it as an investment in the future. Is it possible the message is being heard?

Heilmeier: During the 1950s and 1960s, the so-called glory years, physics was the principal focal point for a great deal of funding from the Federal government. It seems to me that over the last ten years or so, we have seen a shift to much more interest in things like molecular biology and the life sciences in general, as well as the information sciences. One needs to wonder whether, just as physics grew at the expense of other research fields, we are seeing a shift of emphasis in the late 1980s and into the 1990s, this time away from physics.

Goodwin: Since the Industrial Revolution, to be sure, physicists have built a mighty foundation for most sciences. Their culture and contributions pervade so much of science, it is commonplace to speak of the primacy of physics. Physics is considered, in addition, a source of economic growth and development. This accounts for the payback to physics research by government and industry. Are you suggesting that the era of physics as the predominant science is at an end?

Heilmeier: I'm not predicting the end. What I'm saying is that there are now other fields of science that are

capturing the public's attention and the government's support.

Trivelpiece: In my mind it is not so much the question of the primacy of physics as it is that almost no interesting activity today involves a single discipline alone—physics, chemistry, biology, so on. The lines between them have become blurred. In fact, I think academic institutions have a problem in dealing with that because the rigid structure of their department systems, in which promotion, tenure and so on are granted, tends to mitigate against an easy ability for faculty members to move from field to field and to get involved in cross-cutting research or teaching. So it is not a question of physics itself. Look, people talk about the decade of brain research, and such research certainly involves techniques, processes and measurements that originated with physics. Physics is involved in a lot of the areas of the biological sciences. So the question needs to be enlarged rather than narrowed when we consider the field of physics.

Schmitt: One of the problems of physics is that it usually gives over a subject to other disciplines or to interdisciplinary groups about the time it begins to become commercially or industrially important. I think that's been characteristic of the physics community and physics research for a long time. Physicists tend not to follow things they start to wherever they may lead. They go up to a certain point and they then leave the work to people in other disciplines—engineers, chemists, biologists, geologists and so forth. So I think the physics community itself has to a considerable extent limited its role and importance in society.

Lubkin: Can we return to the question I asked at

the outset?

Schmitt: Is science today under stress? I would like to get to the core of that question, as I have begun to understand it after some study of the situation. I think Leon Lederman's survey [see *PHYSICS TODAY*, February 1991, page 75] set off a lively discussion that is exceedingly important. He directed our attention to a certain high level of discontent in the research community. Leon also did an analysis of Federal funding—and I followed his methodology exactly, except to change it a little, using a different discount rate and looking at the total funding—and it turns out that during the 1980s, when this discontent was growing, the country was experiencing a growth in funding. Funding growth was true on a *per capita* basis too. So it really is difficult to associate the discontent with the total level of funding.

Bloch: I want to get back to whether physics research is adequately funded. Obviously, it is not. It never was and it never will be. Is science under stress is not the question either. I would agree with Dan Kleppner that the whole country is under stress. So the question should be how can science operate within this very stressful and changing environment. Singling out physics or singling out all of science by itself is somehow building a sand castle. We have got to look at ourselves in the environment that we live in.

Goodwin: Physics is our metaphor for all the sciences. To Washington agency officials and Senate and House members the sciences seem to be insatiable. No matter how much money is put into a scientific field, it finds ways of spending it all and asking for more. The frustration Leon Lederman has found is not felt only by scientists; it is experienced as well by government folks who are faced with requests each year for higher budgets to pay for new instruments, whether these be supercolliders or telescopes, or for larger research programs for mapping the human genome, say, or ending the AIDS epidemic. Lederman spoke about the discontent among scientists who find themselves shortchanged at a time of excitement and challenge in their fields. He was criticized for whining about the current situation and some even called him a crybaby.

Lederman: I think a well-chosen sob here would be appropriate. [Laughter.] I think Dan and Erich said the right things in the sense that you can't isolate physics and look at it away from the context in which we practice. Irwin is right. We are talking physics but we really mean all of science. I don't think physics is under any more stress than anthropology or zoology. And then, of course, I now know all about the homeless because I've been told over and over again that physicists are better off than the homeless—except, someone has told me, at Berkeley. [Laughter.] Having spent most of last week in my educational activities [in the Chicago public schools], I think education is under stress. The virtue of talking about education is that it's a more widely recognized crisis. But as Erich Bloch has pointed out many times, science and education are both long-range investments in this country and there are not too many others.

In my optimistic mode, I will say that given enough time we will find the leadership that will see that this country will survive if we readjust our priorities and invest them in our human resources. When I look at the various report cards that have come out since "A Nation at Risk" in 1983, they jibe with my own experience in one city—that in spite of all the eloquent rhetoric emerging from Washington and the sincere efforts in the nation's schools, we haven't moved the system very much. And if I ask why, I think it is that the American public is not yet on board. We still have not convinced the general public that education is in a state of crisis and that it is important to repair that. And I think science is way behind. It's much harder to convince people about science. On the other hand, it is the public that has to decide. George Brown and I are the only ones around this table who have been elected to our offices, so . . . [Laughter.]

Lubkin: Let's ask Congressman Brown.

Brown: Since Leon mentions the problem of underinvestment in our infrastructure, I thought it timely to refer to the Congressional Budget Office report on infrastructure and other public investments. CBO divides infrastructure into three categories: physical infrastructure; education, training, employment and human services, which is human infrastructure; and R&D infrastructure. The summary charts trace the investments from the 1950s through 1990. These show that the physical infrastructure moved up until roughly 1980 and has been level or decreasing since 1980. The human infrastructure moved up steeply from 1960 to roughly 1980 and then turned down drastically and has been level for the last five years. R&D, on the other hand, is the only one of the three infrastructure components that moved up to a peak in the early 1960s, decreased up until roughly 1980 and then increased sharply from 1980 to roughly the present time. Now, these lines do not answer all of the questions as to whether we do enough R&D, or how appropriate it is and so forth. But that puts the infrastructure problem in the context in which it is viewed by policymakers. They are going to look at these charts and say R&D is in hog heaven and it is the other two components that are really suffering, so that's what should be addressed.

Now I will tell you very honestly that I agree with Leon that we are not adequately funding research in physics or any other science I can think of, because I see the opportunities and the problems within the sciences. We're not funding all the competent researchers. We're not addressing all the interesting questions. We're being left behind by other countries. For all these reasons, I say we're not funding research enough. But that's not the real problem. The real problem is, How do you set priorities after looking at all the infrastructure components and come up with a reasonable solution? Now, as a very short answer to that question, most studies have indicated we don't have reasonable policy-making mechanisms. We have got to figure out how to develop a brain that will set goals, to provide input-sensing information as to how well we're moving toward these goals, and then based on that information to determine what paths we follow to achieve



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Erich Bloch

those goals. We just don't have that kind of a system.

Trivelpiece: I don't remember the numbers exactly, but I've always used the 20-20 rule—namely, 20% of the budget is discretionary, and 20% of that roughly is R&D. That is always one of the answers to people who say, "I don't understand why the government is so concerned about science, it is not a big deal, it is not a big portion of the budget." It is a big portion of that part of the budget over which anyone has any control in any given fiscal year. I think a lot of our colleagues don't recognize that simple truth. That causes some of the problem, because they look at the size of the total budget and say there ought to be more in there for science.

Brown: I think so too. This weekend I read that the Europeans had made a major breakthrough in magnetic fusion research at the Joint European Torus in Britain. And we're cutting back at those institutions and for those researchers that could have put us ahead in the fusion field. I could name several other fields of physics where we are probably losing our lead because funding is inadequate.

Trivelpiece: That is a case where the United States was clearly ahead for many years and quietly retreated from the field in a way that has allowed the Europeans to acquire dominance.

Neal: In answer to the question that brings us here, I want to state that I think the field of physics is under considerable stress, a conclusion I have reached based on many interactions with colleagues at Michigan and elsewhere. At Michigan, for example, we have hired over 20 new physics faculty over the last four years, and, as chairman there, I have had to deal with the question of bringing into the academic fold several new, aspiring, young scientists. There is no doubt that many of these extraordinarily promising individuals, often selected from a pool of over 200 top candidates worldwide, have had much more difficulty identifying research funding than their counterparts would have had a couple of decades ago.

There are other measures for sensing trends in the field. At the NSF, one of the primary funders of faculty research, the physics division budget was \$116 million in 1985 and \$122 million in 1989. So regardless of which deflator one chooses to use, the trend in available funding gives some clue as to why productive researchers are

having difficulty even maintaining their same level of effort year by year. And when you subject our nation's top researchers to constant scrambling—initially giving up undergraduate student assistants and then graduate students, and enduring a growing number of missed opportunities—it naturally creates a feeling that something is wrong.

Heilmeier: Why has there been such growth in physics at Michigan?

Neal: There is a significant university initiative to expand and improve the physics department at the University of Michigan.

Goodwin: Is there a demand for physics from the students?

Neal: From graduate students, the answer is yes. From undergraduates, it's also yes. Enrollments are going up in introductory courses, and the incoming graduate student class more than doubled last year.

Heilmeier: What was the algorithm by which you decided to increase the size of the physics department at Michigan? Was it internal politics? Was it based on excitement in research areas? What led to the priority change?

Trivelpiece: Homer's persuasive capabilities. [Laughter.]

Neal: I'll roll back the film. As many of you know, Michigan has had a long tradition of excellence in physics. George Uhlenbeck and Sam Goudsmit spent much of their lives there, the bubble chamber was invented there, the $g-2$ experiment was first done there, the first nonlinear optical effects were observed there, we contributed significantly to the invention of fiber optics, we were key players in the IMB experiment, and so on. To sustain this tradition and to meet other university and state needs, the university administration made a concerted decision to strengthen the department. As an example of an area of emphasis in our current building program, we had very few faculty in condensed matter physics a decade ago, and now we have approximately 18.

Bloch: Homer's case history is very illustrative. It points out a couple of things. Just looking at what NSF provides in the way of funding for physics is not the total story. You have also got to look at what else supports physics. It's not just the Federal government; it's the states, the private sector, on and on. George Brown made the point that there is no science policy-making structure in Washington. I would assert that there is no policy-making structure in academia either. Just as Michigan decided for all good and valid reasons to rebuild physics, another university may decide to reduce its physics department. So, I would suggest that we have no policy-making apparatus anywhere in science. It's a random walk. Therefore we shouldn't be surprised that we are faced with issues and with problems that are almost unsolvable.

Trivelpiece: Do you think in addition to an indus-

What you are going to see is that the Superconducting Super Collider is probably going to get scrapped. And you are going to say, oh, that's great, all these other projects then will get more money. The fact is, they won't.
George E. Brown Jr



trial policy we should have a national academic policy?

Bloch: I never said we should have an industrial policy and I wouldn't want to be quoted even if I had said it. [Laughter.]

Schmitt: I would suggest that you don't need policies if you have markets that people pay attention to. And I think one of the characteristics of academic life is that institutions have never thought in terms of what is the market for what they are doing and how well they serve the market. Rather, the typical decision is based on purely internal criteria: "We had a glorious history, we've let it slide and we need to rebuild it" or some variation. That may or may not have anything to do with whether what they are doing is needed out there by anyone, whether the number of students is growing or any other thing. So until physics and the rest of physical sciences sets its mind on what society demands and tries to respond to that rather than looking at our internal priorities, we're going to continue to operate under stress.

Bloch: I agree. I pointed out the problem; you are pointing out a solution to the problem.

Trivelpiece: You wouldn't claim, would you, that it should be exclusively market pull setting priorities? There could also be some market push. Smart people have ideas to do things that the public doesn't yet recognize as important or doable.

Schmitt: That's quite right.

Lubkin: On the subject of markets, I want to ask Dr. Heilmeier about an industrial policy decision. I've been informed that Bellcore has recently decided to eliminate long-term research. Is that correct?

Heilmeier: That is absolutely false. It's totally false.

Lubkin: What is the current policy of Bellcore toward basic research?

Heilmeier: The policy toward basic research has not changed at Bellcore. We have decided to reprioritize our basic research, however. So probably what you are hearing is the lament of some folks who found that their areas are being de-emphasized. I think periodically any laboratory ought to reassess its priorities.

Kleppner: I've heard that Bellcore is withdrawing from the physical sciences. Is that correct?

Heilmeier: That is not true. We're de-emphasizing some areas of the physical sciences and in the process increasing our effort in basic research in the information sciences. But we are not eliminating our work in the physical sciences by any stretch of the imagination. The amount of downsizing that we are going to do, or the shift in priorities, represents a small amount of the total. Nevertheless, to those affected, it is a very serious matter and we recognize that. We are trying to handle that situation as compassionately and as humanely as we possibly can. The process of reordering priorities is not going to occur in one budget cycle. It is going to occur over time to give people the opportunity to make career choices

in a rational way. And there will be no pink slips or rapid changes in direction.

Kleppner: Looking at this as part of a national picture, it appears that there is a cutback of investments in basic research in industry.

Heilmeier: I can't speak for all industry, but I believe your statement is correct. I asked Homer Neal earlier about shifts in priorities at his university. Bellcore is experiencing one of those. Looking at telecommunications in the future, we see it driven more by the information sciences than, for us, the physical sciences. That does not mean we're not doing any physical science research. What it does mean is that over a period of several years we are going to be shifting some of our emphasis more toward the information sciences.

Schmitt: I suggest that one of the phenomena working here is something I mentioned earlier—namely, that the physicists have turned over to information scientists still another area of research that they've launched.

Trivelpiece: Certainly, there was an effect of financial dynamics in which T. Boone Pickens lavished his affection on Gulf Oil and then Chevron took over Gulf and so the Gulf laboratory disappeared in the consolidation. Then Pickens went after Phillips Petroleum and that company, to accommodate the threat, gutted its R&D laboratory. Similar episodes took place for a period, in which industrial research of a basic nature got badly gored in the United States because, as somebody from a Wall Street organization said, looking out over an audience of VPs of R&D: "All of you are a variable overhead expense. Let me repeat, you are all a variable overhead expense." That statement sends a shock wave through a collection of people who live at the margin of the overhead budgets in organizations. Indeed, they have to justify themselves to their corporate masters. In some cases the financial dynamics in the past five or ten years have made the decision to sustain basic research very difficult in boardrooms across the country. Those pressures are not going to go away very soon.

Heilmeier: I think there has been a shift in American industry in general toward more of an output orientation with regard to research and development. For a long period of time, perhaps throughout the 1960s and to the mid-1970s, the process was pretty much input oriented. More was better. But that algorithm is being challenged. Now the orientation is much more toward output.

Lubkin: Do you mean that industry is now stressing short-term research?

Heilmeier: Based on my experience, I would say they are, very definitely. That's part of the manifestation of an output-oriented process.

Lederman: It puts the burden on academic research even more so to preserve the future strength of the country.

Heilmeier: It does indeed, Leon. Unfortunately, in academia, as you folks probably know far better than I, there has been a lot of pressure on university researchers to make their work more "relevant" and more short term, just as we need the longer-term view all the more.

Lederman: I have noticed at sessions of the National Academy's Industry-University-Government Roundtable and at the Council on Competitiveness that there were warnings: Be careful, universities, don't sell your basic research to accommodate to new pressures of commercial competitiveness. That is the perception—that universities, caught up in the stress that we're talking about, may give up on the importance of basic research.

I also would like to comment on a point made earlier about physics. I absolutely agree: I think the population in the sciences, and here again I mean at universities, has doubled. New fields have opened up. This is to the credit as well as to the liability of American science. Of course, physicists will take credit for most of them, but that's okay. [Laughter.] And physics is a much smaller component as a consequence, though physics itself has expanded. I wouldn't say that means physics doesn't have its traditional potential for making us healthy, wealthy and wise. In field after field in physics now there are tremendous potentials.

On the other hand, I don't think physics is going to get out of this mess and leave behind chemistry or biology or anthropology or education.

Heilmeier: I would like to reinforce the point that Roland Schmitt made, and I think it is a very good point, in that when I went to conferences in microelectronics in the 1960s, most of the important players were physicists. As the field began to mature, the major players became electrical engineers. But in the 1960s, there was no doubt that all of the major players, or the majority of the major players, all came from a physics background.

Schmitt: This goes all the way back through history. I mean, Faraday knew about the applications of electricity. God help us if he had stopped [his research] and started patenting things. [Laughter.] He just said, Somebody else will develop this. The same thing happened with Maxwell and with one guy after another. They see the applications but they are busy developing the

fundamental knowledge, thank goodness. And they hope and pray, as often happens, that other people will take over and develop it. That's the way science and technology have progressed.

Kleppner: There were two comments made earlier I would like to pick up on. One was the observation that science has grown enormously and so the relative role of physics is smaller. Nonetheless, it is the key science. Physics often provides seminal theory, experimental techniques and new instrumentation for the other sciences. Beyond that is the fact that physics is going great guns in new discoveries, and the creation of new technologies. One interesting area in which a lot of work is being done at MIT is called mesoscopic physics. It is a new subject that interfaces with quantum physics and microscopic structures. Right now its concerns are basic science. But one can see new technologies down the road. So I don't in any sense accept that physics is less important now than it used to be simply because there are other important sciences today.

The other observation deals with something Erich Bloch said—that physics does not have enough money for support and it never will. I think that is too simplistic. It overlooks the fact that the future of physics in the United States is by no means assured. We take for granted our scientific preeminence. One hears over and over again that our graduate schools are the envy of the world and that we are the scientific leaders. But anyone who is working in the trenches knows that situation is fragile and that we could lose leadership very quickly. The report that Leon Lederman put together is widely criticized for being self-serving and nothing more than a book of anecdotes; nevertheless it is fundamentally correct. It is very difficult to pursue physics today.

Let me provide one more anecdote. I have a colleague whose work had been going well for a long time; the renewal came up; the reviews were strong—but his budget has been slashed. The reason given is that his research is too expensive and that the university could pick up more of the costs. At almost the same time word came from Europe that a consortium has been developed among several of the nations in the European Community to work on the very same subject, essentially on his ideas. This little episode is being repeated over and over again. The handwriting is on the wall. The students who are working on this project know what is happening. They realize how difficult it is to compete, and how unsatisfactory a career is under such circumstances. To deny the reality of that is extremely dangerous.

Schmitt: I agree with Leon's remarks about the importance and key role of physics. My only point earlier, Leon, was that if physics says that's our mission and that's the role we play in the world, then it has got to accept the result that science in total is going to grow more rapidly, because physics is putting a lot of new things out there that show a lot of growth potential and not following up. So I think one thing the physics community has to do is say, what scope do we want to have, where do we want to go, draw the boundaries on what we do and do not do, and

realize that doing that has implications with respect to the funding that is going to occur.

The comment I would like to make on Dan's theme is that fate isn't all fair. In Great Britain, one of the most serious slashings of funding imaginable of research support in academia has been occurring over the past few years. Yet, it is in England that this breakthrough in fusion occurred. I don't think those are correlated, mind you.

Kleppner: The JET fusion experiment is run by the European Community; it is not a British project.

Trivelpiece: I understand. In fact, it had a great impact on the nearby laboratory. The budgetary cutbacks in England resulted in great reductions in programs at Culham Laboratory even though JET survived very nicely because it is a European Community activity. Some of the travail we have here is not unique to the US by any means.

Brown: Well, I was moved to raise my hand because of the discussion of physics and the anecdotal survey that Leon did. Actually, one of the great pleasures of my job is that I get to talk to a lot of different scientific groups. And the physicists are by no means the most complaining. [Laughter.]

But what really ticked me off—a couple of years ago, I spoke to an annual meeting of one of the biological groups and that's all they could think about, how underfunded they were. Others, of course, in many ways give us the same message—the Earth scientists, the astronomers, the social scientists, particularly, because they really are just emerging to be classified as a science in a sense. So there is nothing unique to physics about this feeling that there is underfunding. And as I pointed out to the biologists, if there is any one field that has had the largest, most consistent growth of any scientific field, it is biological research over the last 30 years. And they are complaining the most. Well, maybe only slightly more than physicists, but a little bit more than physicists. [Laughter.]

Of course, their complaints are soundly based. There are a lot of biological researchers out there who can't get grants, the number of applications is going up, grants are going down. And as you all know, they went through this trauma of considering whether the grants were too small and too short in time, and they made some changes there and improved that situation. Instead of alleviating the complaints, the complaints actually went up, because while they recognized that it was a modest improvement for the senior researchers, they weren't getting as many postdocs now because there wasn't enough money available to fund the new researchers.

The point here is that complaints are going to tend to be somewhat insatiable. I don't think that anything we've said so far really addresses the problem. I pointed out, and I'm going to go back to this just very briefly, what the charts show in terms of funding. The charts don't reflect everything that needs to be said. The charts need to be disaggregated and analyzed carefully, and then some decisions need to be made on the basis of some rational procedure. And this is what we're still not doing. Ultimately, Federal funding for research and development is going to be decided by a political process. That process needs to be enlightened, and it is not enlightened

at the present time. But if we consider all of the factors, which I don't think we here at this table are likely to consider because we're looking primarily to physics, and more broadly to science in general, but we're not looking at total national interest and total political pressures, and that's what is going to determine how much funding research and development gets in the Federal budget.

Neal: I would like to endorse the concept that we do need to look at the various components separately. For example, Erich mentioned that the total is important, and I agree with that, but in many areas, I think the NSF is the primary supporter, and in some areas it is essentially the only supporter.

Bloch: That's not true in physics.

Neal: Well, during the time that Erich was there, what fraction of the gravitation physics budget came outside the NSF?

Bloch: I think zero.

Kleppner: NSF supports about half of university research, so it is the largest single player.

Neal: Yes. The point I want to make is that in some instances it does not matter that industry support for R&D might be rising substantially. As someone who has tried to get matching support for Presidential Young Investigators, I can tell you that there is an enormous difference in trying to secure such support for faculty in applied physics versus, for example, astrophysics. So I think there is something to be learned by looking at things at a fairly fine level, especially if you are trying to ask why certain faculty are unhappy.

Bloch: I just want to come back to this question of adequate funding. I didn't mean it, Dan, as a simplistic kind of view saying it would never be adequate. What I meant to imply was something a little bit different. Instead of always asking ourselves how much more funding do we need or is the funding adequate, we should really ask ourselves the question, Are we using the funding that we have in an adequate way and in an optimum way? And I would suggest that we aren't.

Trivelpiece: One of our problems has to do with our perception of adequate funding for research. Some people in the political arena say: "What do those people want? After all, they get more than \$80 billion a year for research." We say, "But that is mostly development work for DOD and little of it is devoted to research." In fact, less than \$10 billion of that 80 is devoted to what we would call research, and this is the part that hasn't grown adequately. What might help is to get R&D broken into its component parts, so that we could examine the relative merits of the various programs, and be able to point out that what has tended to grow is the "D" part, not the "R" part.

One of the other aspects of the perception problem has to do with statistical information provided each year by the National Science Foundation on support of research by the various government agencies. While I was working at DOE, I was troubled by the fact that this data base would indicate that the department was only funding basic research at universities at a level of \$300 million. This fails to take into account such minor institutions as Fermi

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National Laboratory, and other DOE facilities that do not exist for any purpose other than research at universities. If you include all of the elements of its research support, the Department of Energy probably supports basic research to the tune of more than \$1 billion a year, a good portion of which involves academic institutions—a lot more than the \$300 million cited in the NSF tables.

Goodwin: Al, I would like to ask you a question related to setting of priorities. [Secretary of Energy] Admiral [James D.] Watkins attempted to set priorities just the other day with Will Happer and found that one committee had given him some priorities, and that was the Townes panel. Then when the High Energy Physics Advisory Panel and the Nuclear Science Advisory Committee looked at those priorities, they decided those weren't the right priorities; they gave a whole new set of priorities. What happens to the energy research program at the Department of Energy when Watkins's own committee cannot make some basic decisions? Watkins will have to make them, or Congressman Brown and his group will have to.

Brown: I wish.

Goodwin: Somebody is going to have to make those decisions in the end. The Congressman has already spoken on that issue. But I would like to hear from you.

Trivelpiece: Well, first, they are advisory committees, and so they give advice. Basically, the people who are sworn Federal political appointees are the ones who end up, at least with the Administration, making the decision. The elected members of Congress, with the advice of their staffs, are the ones who make the counterpart decisions, and it is done in a political framework. But that means that political appointees should do the best they can to get as much advice as they can.

I think everyone around the table here in one form or another has been involved in this process and knows the frustration of trying to get something of an interdisciplinary decision-making process for deciding the merit of high-energy physics versus solid-state physics versus plasma physics or physics versus chemistry. I don't think that you could probably put together a group of otherwise well-intentioned individuals who would be capable of making what would be perceived by the participants in any given field as a fair and objective choice on the priorities from field to field. It just cannot be done. I think that the Townes panel did a fairly good job of trying to come to grips with it; they gave honest advice based on a circumstance of being told that there was a constraint on the budget.

Now maybe the answer should have been, Well, you should go back, Mr. Secretary, and try to get a bigger budget. That would be another one to say, "Is it the obligation of the Secretary of Energy to simply go and do battle on behalf of the science community to get a larger budget?" He has his own priorities that he has to deal

with, which include the environment, safety and health, and the pressure on the national scene that comes from the Congress in many cases to clean up some of the DOE facilities. It is a very complex political situation, and the Townes panel and all the other panels are simply one input that the Administration needs to use. But it is not the final determiner of these things.

Brown: Let me comment on that point because I was very much interested in the Townes panel and the charge that they received to look at the physics programs in the Department of Energy and adapt to a static or declining budget but not to consider the Superconducting Super Collider. I am seriously disturbed, and I wrote to the Secretary about that, because I think that spells the doom of the Superconducting Super Collider. Many of you are going to say that's just fine; it ought to be doomed anyway. It is another space station kind of debate.

I have said over and over again that the Superconducting Super Collider is the cutting edge of science, and the space station is marginal in terms of scientific contribution. But that's not the type of thing that I'm trying to say here.

What I am saying is that what you are going to see is that the Superconducting Super Collider is probably going to get scrapped. And you are going to say, oh, then all these other projects will get more money. The fact is, they won't. You'll find a declining budget for the Department of Energy and the money that they do have is increasingly going to go toward the nuclear cleanup and some other things like that. There is a whole series of very important policy decisions we're now in the middle of in the Department of Energy that are all interrelated. And unless you understand the interrelations, you're not going to be able to have a very highly regarded input to this process.

I don't like it. It wasn't Watkins who made the decision to keep the Superconducting Super Collider



What I miss in our country today is a sense of the future. We seem to be dealing with emergencies and paying for the years of neglect. In contrast, science looks to the future. If this country is to have a future, science must play an important role.
Daniel Kleppner

healthy but cut the others. It was the Office of Management and Budget that made that decision based upon their projections of the budgetary situation, and it's totally arbitrary. At the same time they are proposing to cut the Department of Energy, and many other things. Of course the Federal debt next year is going to skyrocket again. It is going to go from \$300 billion, more or less, to \$350 billion, more or less. The question is not that by cutting this can we balance the budget; it's just how much borrowing do we want to do. And that's something we need to look at in terms of realistic evaluation.

Trivelpiece: Although I don't sit on the budget review committee for the department anymore, there does occur a period in which decisions about putting money into research, uranium enrichment or cleaning the place up have to be made. Those are the macro decisions that have a great influence on the outcome of these events. Would a billion dollars, more or less, devoted to the pace of cleaning the departmental sites up make as much difference to the benefit of the country 5 or 10 years down the road as preserving a research infrastructure that has taken 20 or 30 years to put together?

Apparently the question has been decided within the department in favor of the cleanup, and DOE would say that's probably as a result of pressure from the Congress to do so. If that's the case and there is the discretionary budgetary cap, now with this Budget Reconciliation Act they have no choice, as the President parsed out the budget control numbers to the department to do it in this way. Now, that is only the President's proposal, and the Congress will get to have a hand in the disposal of this. I don't know how it will come out this spring, but I suspect it will be a fairly lively session.

Brown: It will be lively, I can assure you.

Heilmeier: I think it is interesting to note that in spite of the fact that the Defense budget will obviously go down, Secretary Dick Cheney and Deputy Secretary Donald Atwood have made a commitment to preserve and, indeed, support modest enhancements of the basic research activities of the Department of Defense, recognizing this infrastructure issue.

Trivelpiece: But there is an issue of examining the DOD laboratories. There is some question about base closings and laboratory closings that go together. How do you relate that to the statement just made?

Heilmeier: For the most part, that's really a separate issue. The commitment has been made to continue the support of basic research in the Department of Defense at the expense of hardware. In the face of substantial budget reductions, at least one Cabinet member has decided that they are going to preserve the basic research infrastructure.

Brown: They may also increase applied research in certain areas.

Heilmeier: I think that's right.

Brown: But not the large-scale weapons technology development. That's right.

Schmitt: But, George, isn't it true that those areas didn't share in the rapid growth of the DOD budgets over the past years either? In other words, it's true they are preserving what they had. But on the other side of that thing, they didn't grow as rapidly.

Heilmeier: I think over the last decade there has been steady but modest growth in the basic research efforts of the Department of Defense. But I think it is significant that Secretary Cheney and Secretary Atwood made a commitment that in the face of large cuts they were going to continue their basic research efforts. That's a very wise thing for them to do, right? It is a part of the budget they are retaining even with the changing world situation.

Trivelpiece: Secretary Watkins has made similarly strong statements about the value of the research programs of the Department of Energy. Even so, he has also had to face up to the constraints that are imposed on him by the Presidential budgetary process.

Neal: I would just like to make a provocative statement—that perhaps there can be no setting of priorities substantially improved over what we're now doing. I mean. . .

Trivelpiece: You mean it is marketplace driven? You would claim that the marketplace of ideas is what is actually driving this?

Neal: Absolutely.

Lederman: I tend to agree with you. I don't know any rational way, except there are certain general guidelines. For example, there is how much basic versus applied perhaps. You can look at that balance now and ask whether it's reasonable. How much facilities, so-called big science versus individual investigator? Is that balanced? To that extent I can see a science policy, whatever you want to call it, but I agree with you that there is no rational way. And if you read the Office of Technology Assessment report or you read the [Industry-Government-University] Roundtable report, it is so fuzzy, it reminds me of educational assessments. [Laughter.]

Neal: The tensions that are there are often viewed as being very inappropriate. But they are what make us come out with a bottom line that is pretty close to optimum, I would say.

Schmitt: I agree with the comments made. The only implication is that then we have got to make sure that we've got the right individual decision-making processes out there. And I think some of the problems today probably stem from defects in how the system is working in making these hundreds and hundreds of individual decisions.

Lederman: I can't imagine Michigan didn't in fact consider, before they went to physics, some of these global things and the markets. I'm sure they knew of them.

Neal: Absolutely. We have invested an enormous amount of time laying out our development plan, drawing heavily upon external visiting committees and taking into account the needs of our university and our state. We have chosen very carefully the areas we want to build in.

I also want to say something about the SSC, the Townes panel and those issues. In my estimation, the SSC was rather well planned. Back in the days when you were at DOE, Al, you thought highly of HEPAP's ability to make tough decisions. It made a tough decision about the SSC. There were certain guidelines that were specified about what was, or was not, going to happen to the rest of science were the SSC to be approved. And it was against that background that a decision was made. We can't blame HEPAP for the fact that someone decided rather recently that he or she needed an extra couple of billion dollars to clean up radioactive wastes that we had nothing to do with. The process worked pretty well, except for these things out of the blue that are now generating the crisis.

Goodwin: Homer, you will recall that it was Al Trivelpiece who said that the SSC would not be funded at the expense of other sciences.

Trivelpiece: Well, I appreciate that, Irwin, but it was, in fact, the President who said that.

Goodwin: Nonetheless, you wrote his script. [Laughter.]

Trivelpiece: It's in the decision memorandum. The Administration and the Congress have different abilities to deal with problems. To the extent that the Administration can make such a statement and make it stick, it said that the SSC should not be funded at the expense of other basic research in the nation. I think it was said with conviction and honesty. Time and circumstances change. The Congress has 13 appropriations bills. It has to deal with this differently. There is the 302(b) allocation process. The political climate has changed in the meantime. So now the question is, What do you do in the present political reality climate?

Well, the Administration can do the best it can to live up to that. It probably isn't in this case. The Budget Reconciliation Act certainly has an effect on it by having put caps on the discretionary, defense and foreign aid [budgets], and now the Administration is trying to deal with that, and it has its own priorities. So perhaps [the SSC] gets sacrificed at that margin. But there is always the process of the lively debates in the spring, which will

undoubtedly add something to this or subtract something from it.

Brown: I want to comment on the outrageous statement Dr. Neal made that the present system is optimal for anything. [Laughter.]

It really isn't. And it is not because the process is not multifaceted and pluralistic and all those good things. To that degree, I agree with you that the system is a good system. But the various parts of it are not working well. My concern is that until the various parts begin to perceive their role as parts in a much broader sense that contemplates the whole, the system is not going to work.

For example, we've got to understand the tension that exists between support for basic research and for applied research and technology development. We don't understand that tension yet. We don't understand how the health of science links with the health of the economy, and how physicists' being out of work is complemented by a lot of factory workers' being out of work. We don't really have a sense of the big science-little science issue and understand it in terms of the contributions that little science and big science make both to the field of physics and to the whole of science. The problem occurs in many different disciplines.

What I am suggesting here is that we could improve upon the system, assuming that the framework is reasonably good—and I think you can make an argument that it is—if we would each seek to have a little broader sense of how all the parts work together and assist in the total process. That's what a brain is for, setting goals and priorities and then working out strategies to achieve them. We cannot do those vitally important things unless there is this broader comprehension. It's lacking in the Congress and it's lacking in the scientific community, in my opinion.

Heilmeier: Do you have any suggestions for how you could develop this or articulate it? What's the mechanism?

Brown: I think it's not something that you can create by a dictum. The best example I can give you is the example that we're going through in improving the quality of American industry through the Malcolm Baldrige Award, which puts a great deal of emphasis on each entity's exploring within itself what it's doing right and what it's doing wrong, and then spreading its wings, doing something to improve its industrial productivity, its management of human resources, its outreach to its suppliers.

There are analogies to each of these with each of your own positions, with each of the scientific disciplines. You need to be looking outward to see how the total entity contributes to the welfare of the whole in many different ways. Physicists should remember that research is only one thing that physicists can do; they are also educators and they know they are educators. They do a good job of educating. But I don't hear very much talk about that compared to the talk about the lack of funding for research. They are people who create the tools for other sciences; they create the applications to new ideas for productivity.

One of the problems of physics is that it usually gives a subject over to other disciplines about the time it begins to become commercially or industrially important. So I think the physics community itself has to a considerable extent limited its role and importance in society.

Roland W. Schmitt

Overall, nobody is thinking about the question of whether this great society of ours is moving in the right direction. I have serious questions as to whether it is, and I don't see very many scientists questioning whether it is or not.

Heilmeier: I would like to develop a variation on the theme that Congressman Brown developed, and that is, I hear many of my friends in academia telling me that overhead expenses in universities are sapping more and more of their productive R&D dollars, and that these, they feel, are not controlled by universities and that consequently they are suffering. They bring in contract dollars and they don't feel that they are getting all of the value that those dollars could bring to their research efforts.

Of course, overhead is a necessary evil, and I don't think they are complaining about that. I think they are complaining about the fact that they feel the increases in overhead in universities are in many cases growing much faster than their ability to accommodate them, and they are growing in what they perceive to be an uncontrollable manner.

Trivelpiece: The same exact statement could be made in national laboratories right now.

Schmitt: Yes, but the facts are different. The fact is that during the 1980s, the overhead rate for NSF contracts had been flat. It has gone up at NIH some but not an awful lot basically. So that complaint is just another manifestation of the general tenor out there that is not based on good fact, George. I'm sorry about that.

Heilmeier: I'm curious about that, because obviously somebody must be picking up the overhead, because medical expenses have gone up, insurance expenses have gone up, practically every commodity is going up and you're saying that the overhead rate has remained constant.

Schmitt: The overhead rate at my institution has been going down in the past eight years.

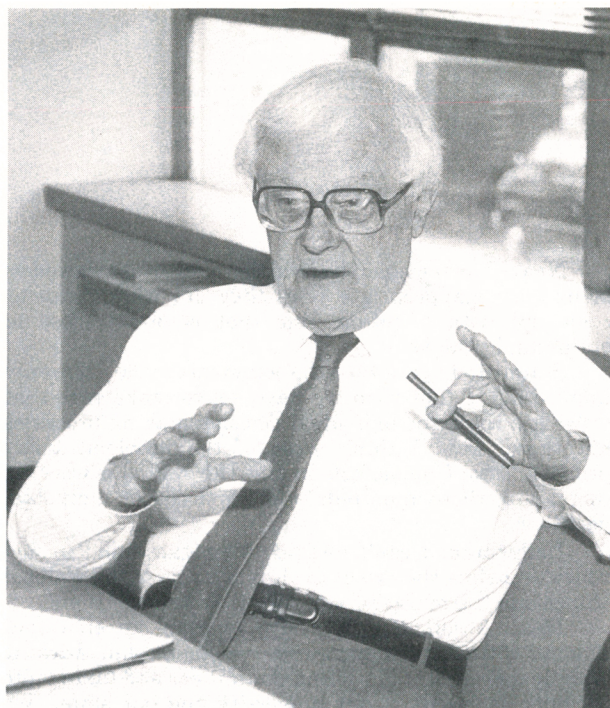
Bloch: That the overhead rate at NSF has been flat is not an indication that the overhead cost in an institution has not gone up. It is being absorbed by the institution rather than NSF.

Heilmeier: My colleagues in universities tell me, "Please, if we're going to work in a collaborative manner, give us grants; don't give us contracts because somehow the overhead rates aren't applied to the grants, and they are to the contracts."

Schmitt: George, having sat on both sides of that, I deplore some of the practices I previously had. [Laughter.]

Heilmeier: And denounce them soundly. [Laughter.] It is a question of whether not a researcher wants \$100 000 to spend on his research or \$75 000.

Kleppner: I think it is a question of whether the Federal government is going to pay the full cost of the



research or not. In the past, in the glorious years, the assumption was that the Federal government would pay. Now Erich has made the point that there is a lot of other money out there, but I don't know where it is. You look at major universities having budget cuts. The University of California at Berkeley had a 10% cut; Stanford had a cut; Yale has had a cut; MIT is running on a slight deficit right now. The question of trying to recover these costs and pay for the research becomes a crucial one for the universities.

Should a university take away money from the undergraduate scholarships in order to pay for graduate research assistants? This is what is being asked. From that point of view, I am very regretful about one of the policies that I know you felt was a very important one—namely, cost sharing—because the money isn't there to share. And universities are being squeezed more and more, both the private universities and the public universities.

Heilmeier: Is it time for universities to begin to reengineer their practices in much the same way that industry is doing?

Kleppner: Well, if we could have the overhead rates that industry had, we would be rolling in money, I think, because the cost of research at universities is low.

Bloch: The 80% overhead rate in our universities is not that far away from what it is in some private companies.

Trivelpiece: You have to look at the details, the direct-indirect contributions.

Kleppner: I think by any standards the cost of research in universities is cheap. One reason it is cheap is that the research is done by graduate students and they are a great bargain. Beyond that, the overhead rates in universities are certainly not high compared to industry.

Trivelpiece: I can prove it is cheaper in any one of the three sectors given somebody who doesn't understand direct-indirect ratios too well.

Bloch: I want to come back to Homer's outrageous statement. [Laughter.] Which I don't consider outrageous, by the way. I consider it an abdication of control.

Neal: That's even worse. [Laughter.]

Bloch: I want to link what George Brown has been saying and also what Dan or Al mentioned before when they talked about policy being mushy. Yes, it's a mushy subject; it's not an exact science. It will always be mushy. But I think we have made some progress toward a coherent policy at least in certain areas. I want to single out the revived or rejuvenated FCCSET [Federal Coordinating Committee for Science, Education and Technology] process. I think where it addresses specific disciplinary or better yet multidisciplinary areas, as it does in materials science, as it did in the 1992 budget in high-performance computing, you see for the first time a coherent strategy across the Federal government.

You're not going to solve the problem from one day to the next. You can only approach it and improve on it slowly. But if the scientific community doesn't make the decision or doesn't think it can make the decision, somebody will make it for us, be it Congress, the Administration or a combination of the two.

Lederman: To me that's not a threat. I think if scientists had to make the priorities, the blood that flowed on the floor would not be worth it. It is not a threat to say that the system of priorities that has grown like Topsy, or has evolved, is better than an artificial system where you force scientists to decide between atmospheric chemistry and plate tectonics.

Trivelpiece: Why should the choice always be made within that arena? Why shouldn't it also have the opportunity to be made against the budget for agriculture or some other larger macro element of the Federal system?

Lederman: You don't want scientists to do that.

Trivelpiece: Several of you have had the misfortune of having me inflict on you a talk. The talk would contain in it an element about how scientists, like the pioneers of our nation in crossing the Great Plains, recognize a threat and circle the wagons, but unlike the pioneers, we tend to shoot inward. The problem is that if we try to cut the budget, the physicists go up and say: "Take it away from the chemists. Don't take it away from us."

We are not very politically sophisticated collectively. And that troubles me because now I think it is important to be that way, whereas 15 or 20 years ago it just didn't matter. Now it does matter. George, how should we, as either physicists or scientists, more globally begin to play in the arena in a way that makes us more sophisticated and credible players?

Brown: I'm doing my best to make a case in Congress that Federal funding for research and development for the science and technology infrastructure is less than it should be—the same case that many of you are trying to make and that Leon was trying to make for physics.

I have to do that, however, within the context of a broad set of considerations as to what priorities should be for the total Federal budget. It will be extremely difficult to make that case unless I can point to the fact that there is an understanding in the scientific community that all budgets are under stress—science and others—and that we have to make a very strong effort to demonstrate, as Erich and others have pointed out, that we're getting the

best productivity from the dollars that are being invested.

We would have to do the same thing if it were not R&D but the other two components—physical infrastructure or human resources infrastructure. We're not going to make the case for increasing these unless we can demonstrate that the money is being used as well as it possibly can be through the wisdom of human beings. I don't think you can make that case in every field of science except on the very broad kind of a basis that anything we do to encourage innate human curiosity is intrinsically good and therefore has to be supported. That's not going to be enough.

Heilmeier: It could very well be that if one looks upon the Congress as the investment banker, perhaps the scientific community ought to begin addressing the kinds of questions that investment bankers generally address—namely, explain very clearly, with no jargon, what it is we're trying to do; explain very clearly, with no jargon, how it's done today and what the limitations of current practice are, articulating what is new and what is the opportunity, what's new in our approach and why do we think it can succeed, and assuming we are successful, what difference does it make. The age-old blocking and tackling questions of "How long is it going to take?" and "How much is it going to cost?" and what have you are the midterm and final exams.

Lederman: I think that's right except that I'm not sure it's the Congress that is the investment banker; it's the people, the general public, that are the investment banker in this case. I think in some sense we are doing and have done a reasonable job in communicating with Congress. There is a lot more to be done there. But you do far better in helping a Congressman understand science by developing the public attitude toward science while the Congressman is watching. And, again, I have to include education and say that is a vital constituent of the system.

If you take the kind of science research I know about and the Federal investment in education, you are talking about 3% of the Federal budget, or some number like that. Where is it written that in the 1990s we should spend 3% of the Federal budget on science and education and 20% on national defense? Now, I am looking at it from a long-range point of view. Being the oldest here, I probably do tend to look at the long-range view.

The world is changing. In today's *Washington Post* there was an article about Vietnamese reassessing the value of the war that they fought so bitterly for such a long time with such tremendous losses. Americans have been restudying that for years. Here and there, there are discouraging signs, as in Yugoslavia—but there is a change in this world. And I think the change is going to be fought out on the economy and on ecology and on the standard-of-living gap between the Northern and Southern Hemispheres. All kinds of issues appear that are different from the old issues. And because of these differences, I think that 3% is going to zoom up at some point to maybe 10% or 12%. It has to be that way if we're going to survive. The question is, How do we get from here to there, on what time scale, and what do we have to do?

We have to somehow develop a strategy for under-

standing many of these issues that Congressman Brown raised, and then just as you said, George, so eloquently, selling to the general public as the investment banker. Then the Congress will go along and the Administration will go along.

Brown: Well, this moves us in the right direction. Leon has always understood although not always perfectly enunciated the necessity to recognize the need for the public to be brought into this; they have to perceive the importance of these investments. But you are not going to be able to increase the investments in R&D from 3% to 10%, although I support that under any conceivable scenario that I've been able to think of, including that investments in physics are going to contribute to the productivity or the economic welfare of the country.

Those arguments don't wash because Japan and Germany, without making those investments, both became superpowers economically. And there are other things you have to look at in order to get to that point. What we need physicists to do is to look at those other things also. I'll concede that physicists are the smartest people in the country and if they just apply their minds to it they can run this country better than the politicians. [Laughter.]

Lederman: That is such an outrageous statement. [Laughter.]

Brown: Let me give you an example from another field. Biology has gotten funded primarily because of its relationship to human health. We now spend more on biological research and development than any other industrial country in the world, and we have the poorest health system. The physicists can do the same thing. We can spend proportionately the same amount as we do on biology and all that sort of thing and end up having the poorest industrial system in the world very easily. I can show you how to do it. I'm just saying that there is not necessarily a connection between the investment and the outcome. You've got to see the whole picture. That's what I am pleading with you all to do.

Lederman: As academicians say, it's necessary but not sufficient.

Brown: Yes.

Schmitt: I want to go back to Leon's wonderful report here. When you read it, he really gives the rationale for why science and technology are important to the nation. He says they are providing the basis for new industry to enhance the quality of life, improving general health, understanding ecology and the environment, developing alternate sources of energy, all these things. As I pointed out in one of the talks I gave, that set of reasons is absolutely valid and understandable by the public at large. The defect was that Leon didn't stick with that; he went to the other argument that we need to support all the people out there whose morale is low.

I think, Leon, you should have stuck with the real reasons why physics and the rest of science are important and started to try to relate what we do to those purposes and to get across the notion to the public that science is absolutely the only activity in our whole society that not only creates new wealth but creates new sources of wealth.

Those are the messages that will cause people to want to support you strongly.

Lederman: Let me just read something. I write in the preface: "Although the report may perhaps reveal indications of passion and advocacy, my concern is not for the unhappiness of my colleagues in science, much as I love and value them. My concern is for the future of science in the United States."

Schmitt: I understand. I think it is a wonderful report, except you obscured the important fundamental message by getting people's attention on irrelevancies. [Laughter.]

Brown: Let me just say again, very, very quickly, you can take all of those physicists who are not being funded for research and put them to work on technology transfer and do a better job of rejuvenating the American economy.

Trivelpiece: One time when I was testifying before an Appropriations committee, one of your colleagues asked me, "How can you come up here and ask for billions of dollars to study quarks and other such things?" He said, "I've got farmers back in my district killing themselves for the lack of a few dollars of mortgage money!"

I had the wits not to try to answer that question at the time because it is a very tough question. It was asked by an individual who is a good friend of science, one who has supported science very strongly. His problem is that when he goes back to his district to run for reelection, the people opposing him say: "Do you know what so-and-so was doing in Washington? He's supporting those folks who want money for fill-in-the-blank when in fact what we need in this district is money for..." That makes it very tough for him to be a strong supporter of science. We do not do a good job in helping our friends in the Congress in this kind of political activity. We do not go out to the various Congressional districts and say, "This is why science is important." We need to ask questions of candidates at fund-raisers or other political rallies. "What is your position on acid rain? What is your position on global warming? What is your position on the SSC?"

Until we start to do that and get involved in the process, I think we're always going to be behind the power curve in terms of having an influence over the outcome of this more macroscopic issue of should there be a larger percentage of money devoted to research. It may not be tasteful to most of us, and most of us tend to be apolitical and in fact regard politics with some disdain, but I think until we overcome that and begin to play in the game, we are always going to be confronted with "How can you ask for money for this when I've got people killing themselves for want of a few dollars in mortgage money?"

Heilmeier: Some of the people around this table have served in the Federal government in one capacity or another. I am reminded of a story that a former director of DARPA told me. When he was trying to attract solid professional scientific help in DARPA he had extreme difficulty in getting people to come and be part of the process. It is very easy to sit back in a university and say, "We're not getting enough money; the priorities are screwed up; the Federal government doesn't manage science and technology very efficiently," but when invited



Bellcore is experiencing a shift in priorities: We see telecommunications in the future driven more by the information sciences than, for us, the physical sciences. What that means is that over a period of several years we are going to be shifting some of our emphasis more toward the information sciences.

George H. Heilmeier

to participate for several years in the process, it's very, very difficult to get the kind of leadership from the university community to come into the Federal government for a short period of time, or relatively short period of time, to make a contribution and experience the process.

Schmitt: Gloria, you said earlier we're going to get around to talking about what do we do.

Lubkin: I thought we were trying to do that for the last hour, but please start if you have something to say.

Schmitt: I think we were touching on this a moment ago: How do we get the public as represented by the Congress to appreciate the value of what we do and the contributions that we make? I think it has to start with our own commitment and our own belief in that value. I am concerned that in the physics community that commitment is not sufficiently deep, sufficiently intense, and that conviction is not as widely held as it needs to be for physics to be effective in getting that message across to the public.

One thing we have to do is have some discussion within the physics community and develop further understanding of what role we play in society and then decide if we are committed to playing that role, committed to making physics work in that way.

Brown: The physicists have got to be involved in making some strong cases here. I've said a lot here about the need to interconnect the sciences with the other policy apparatus and parts of our great country. I support the 10% goal or almost any other goal that you set for science because I believe that our fundamental infrastructure in this country is informed by enlightened human minds.

I don't like to make the argument that physics or any other research and development contributes to creating more hardware, or even better hardware, because that course for our society hasn't been all that productive up to now. It misses the real element—that this country will achieve progress when it develops its human resources. That's really the important thing, including physicists.

The problem of the physicists and most other scientists is that they see that as important for their discipline but they don't understand that 90% of the population are not researchers, they are not physicists, they are not

chemists, and they have a right to be included in this total concept of human growth just as the scientists do. If they are hugely out of work and the quality of their life is declining, they're not going to be very happy with what they see as having contributed to that. And that's going to include politicians and researchers; generally speaking, they are not happy with either group. Because this is the bulk of the population, their rather irrational response is going to affect all of us.

I'm making this point to get you to think in terms of how what you do can be related to the desire of all of us in this population to seek growth in our opportunities for mental, cultural and other kinds of development. Until we get that, you're not going to have enough influence as scientists to counteract the discontent that I get every weekend when I go home, for example, in terms of how to spend the dollars for these various programs that we allocate.

Heilmeier: I would like to get back to the point that you made about having people come in to the Federal government—scientists, engineers—to participate in the process. The ability to do that is very seriously hindered by the fact that there are certain conflict-of-interest rules and regulations that make it almost impossible for you to practice your profession after you leave the Federal government. I'm thinking particularly at the Department of Energy and the Department of Defense.

If we really do want quality scientific and engineering input into the process, we need quality people at all levels in the Federal government, and these aren't necessarily career people. In order for that to happen, we're going to have to make it possible for knowledgeable people, people with management and leadership skills, to come into the Federal government for their sojourn and then leave the Federal government and still be able to practice their profession.

I left the Federal government, Congressman Brown, in 1977 primarily because as I read the conflict-of-interest rules and regulations that were coming into effect at that time, it would have been extremely difficult for me essentially to have the freedom to practice my profession. I would be constrained for a period of three years.

Trivelpiece: George, it's easy. All you have to do is take a vow of poverty going in and a vow of ignorance going out. Maybe I got it backwards. [Laughter.]

Brown: But that's the kind of outreach thinking about how the system can be improved that we all need to be doing. I don't understand how a qualified senior professor, for example, at a good university, making about as much as a Congressman, would want to go into the

Federal bureaucracy. They will be making less than a Congressman, as a matter of fact. They will miss a lot of professional opportunities; they have to give up something; and they suffer all of the problems that you have mentioned there.

Schmitt: I want to go back to Congressman Brown's stress on human resources, which I think is a very, very beneficial position to take here. One of the problems is that in academia today research and education are parting company in many, many cases. That really was the concept that Vannevar Bush had when he said let's do our basic research in academic institutions.

What is happening today is that the academic institutions have become kind of holding companies for research entrepreneurs, so that everyone is out there on their own trying to scramble for resources to fund themselves, on the one hand, and on the other hand, the teaching function, the human resource development, has been left as an institutional responsibility. So there is an increasing dichotomy between these two functions in American institutions of higher education today. And that is becoming especially intense among the young faculty, the young beginning researchers, these 20 people that Homer hired. I believe we have got some rethinking to do about how we address that within academic institutions.

Lubkin: We've scarcely touched on industry. We briefly talked about changing goals within a given company or a given industry. Is there anything that government can do or that industry can do to enhance the support of research in this country, or would it again be every person for himself, as Dr. Schmitt was just saying?

Bloch: Let me make two comments; both of them have to do with your question on industry. One is really a corollary to the problem that George Heilmeier was pointing out of attracting people into the Federal service and the handicaps of doing that because when you leave, where are you going? The corollary is very important. It's getting advice into the Federal agencies.

That is also a problem. The Advisory Committee Act and things like that, or their interpretation, are a handicap today. For instance, PCAST [the President's

Council of Advisers on Science and Technology] has the severe problem of getting advice from industry into its deliberations because of this advisory act or at least the way it is being interpreted. I think that is something that needs fixing if we don't want lopsided advice or no input to policy matters that affect us all.

The second comment is on industry. I think we see more and more companies joining together in doing precompetitive R&D. You see companies and government laboratories getting together. You see companies and universities getting together. Now I must admit that it's highly sector dependent. There are some sectors where that is not going on; there are also sectors, as in computers, where that is a way of life. I think we're in the middle of a change that could be highly significant not only to the country but also to academia. And academia needs to understand that and participate in it. I'm not so sure that has sunk in yet. But that's a major change that is going on and for good reasons. I think we should all take advantage of it. It could be to the benefit of science and to the benefit of academia.

Neal: Erich, I believe you've been involved in discussions about an industry-national laboratory study.

Bloch: Let's do something. We've had enough studies.

Neal: I was going to comment that the Center for Strategic and International Studies is forming a working group. I'm supposed to cochair it with Senator Bennett Johnston, and I think that is going forward. One of the goals is to try to find ways in which industry and national laboratories can cooperate to help with issues of getting findings from the national laboratories into industry as soon as possible. So at least that is one step.

Trivelpiece: Representative Brown left a question on the table about what to do about people coming into the Federal service. I think one simple way is simply to give the President, and only the President, the power to grant waivers, and if anybody abuses the privilege of such a waiver, send them to jail. Let the Government Ethics Office provide the advice and consent within the Administration. But it shouldn't be a blanket type of a capability or power to the President; it ought to be a very narrow one



Engaged in finger pointing,
Schmitt (left) and Trivelpiece
(right) get Kleppner's attention.

For a period industrial research of a basic nature got badly gored in the United States because, as somebody from a Wall Street organization said, looking out over an audience of VPs of R&D, 'All of you are a variable overhead expense.'

Alvin W. Trivelpiece



that he uses in order to provide relief to people who need it, who want to serve and would find the present circumstances too burdensome.

Heilmeier: I think in the Department of Defense it is the Secretary who has the right to do that. He has not chosen to exercise it very often, simply because if you ask the Department of Justice what constitutes conflict of interest, they will give you some very, very general guidelines but not very much in the way of specifics. And the bottom line is, "We'll see you in court" to determine what constitutes conflict of interest.

Trivelpiece: Yes. I've had this lecture. [Laughter.] If you look at, say, 1972 or so, the Administration had scientists and engineers in the AEC, the NSF, a lot of them in key positions. Those were technically rich organizations managed mostly by technical people. As a result of the Congressional science fellows, the Hill now probably has more young scientists advising on various areas of science and technology than the Administration has. This evolution has taken place over a 15- or 20-year period. I think it's great. What the Administration needs is the equivalent of a science or engineering fellows program similar to the one that is available to the Congress now. It would be a real aid to them.

Lederman: I would like to get back to the crucial question of this discussion. The question—and I think, again, Congressman Brown raised some very sharp issues—is "Is our science healthy or is there, in fact, an incipient nation at risk?" to borrow the metaphor from education, in which by the time "A Nation at Risk" was written, the infrastructure had crumbled so badly that here we are nine years later and not doing too well in trying to restore it. Is our science going to follow education? How do we measure it? We measured it in perhaps a stupid way by writing letters to people we thought would be the winners and they weren't so happy about it. Maybe there is a better way to measure it. It's not easy to measure but I think it is an important thing to do.

The next question is, "What level of science is appropriate to the United States of America facing the 21st century?" We need the greatest of statesmanship to try to judge that. How do we institutionalize the notion that people seem to agree with, that we have to communicate? There is the AAAS, in which some of you here are involved, a good organization because it is across the board—social sciences, everybody, in it. Is that a good institution to take on as a major function the raising of resources needed to make a much more thorough communication with the public?

Again, it's not only communicating with the public to sell science, it's contributing to the science literacy in this nation. Illiteracy is a terrible word to use for a modern industrial nation. And educating the general public on the issues of science is a noble cause. In addition, it teaches not only the power of science but the weakness of science,

the incapability of doing certain things.

I think this is what I would like to see out of a group like this, which consists of both careworn bench scientists and great Washington minds. Some way, I believe, we have to institutionalize our concerns and educate the general public both on the crisis of science and the crisis of education.

Heilmeier: Would you target the media first?

Lederman: You bet. How else do you reach the public? With the AAAS, we have begun the foolhardy notion of trying to get prime-time commercial television about science. Perhaps replace one of those dreary sitcoms with maybe a better sitcom or some other program which has socko entertainment value but also teaches a little bit and explains.

Lubkin: Leon, is the hero a high-energy physicist in your sitcom?

Lederman: Yes, we could do that, or Dan has given me some ideas. We've now written to a large number of fields of science asking for ideas. We did meet with CBS and got a nice lunch; it was delicious. [Laughter.] And whether they rolled their eyes after we left or not, I don't know, but we do have the next step. They invited us to come back and talk more specifically about this.

Neal: Leon, following up on what you just said, is it your sense that the critical link in funding for science is the executive or the legislative branch? I've always had the sense that Congress was more supportive of what we were about.

Lederman: Homer, I think it is a little bit like this. If I go to see Congressman Brown or Bennett Johnston and we talk for a half-hour, he listens very politely to my message, whatever it is, and maybe he takes it seriously. But if the same message is put into an op-ed article or an editorial in a newspaper or a TV feature, it has a million times the impact on the decision-maker.

Heilmeier: Those of us who testify before Congress know that the best way to prepare is you read every single editorial page you can find for two weeks before you go before the committee.

Neal: Clearly, it is important for us to make efforts on all fronts to inform all constituencies of our needs, and I am only trying to get at the question of where the most

We still have not convinced the general public that education is in a state of crisis and that it is important to repair that. And I think science is way behind. It's much harder to convince people about science.

Leon M. Lederman

critical links are. For example, in science education, Congress is almost always willing to put more money in than the executive branch asks for or is willing to accept. If we have limited resources for articulating our needs, should they be targeted more toward the farmer in Iowa, whose senator and Congressman may already tend to support science, or to better informing the executive branch?

Lederman: It's easier than you think to get the public to support science—again and again, I have heard the same thing: “I believe you, but how am I going to explain it to my constituency?” I think amazing things can happen. One election in Philadelphia and suddenly the tone changes, or look at the amazing political events and the speed with which political events are unfolding, which is due to communications, which is due ultimately to physicists. You throw a rock in Ulan Bator and somebody in the Amazon knows about it before the rock hits.

I think the way you change things is you talk to the general public. If you get an audience, you'll find, looking over your shoulder, decision makers in the Congress and the Administration. They are beginning to see the message as a question of consciousness raising. Now there is a group, the biomedical people, that actually organized something called Research America! They are beginning to do things, you see these 90-second TV sound bites with a doctor explaining to the parents of some child that it's a rare disease, I'm sorry we can't do anything about it, our budget was cut last year, it's terrible. . . . [Laughter.]

Trivelpiece: This is the sitcom you want to put together? [Laughter.]

Lederman: No, no.

Trivelpiece: The Willy Sutton theory of banks, of course, is well known. And what I found that is interesting among our colleagues is almost a lack of recognition that most of the budget gets made up in the dark inside the Administration and there's very little effort to influence it. Or, if they do try to influence it, it is usually too late. Our departed friend George Pimentel came to me one year with that chemistry report, a superb report, that clearly outlined what was needed for chemistry. As sophisticated as he was about the budget cycle, I found it interesting that he showed up in my office late in August, handed this thing to me and said, You'll be able to adjust DOE's budget to take into account some of these recommendations, I hope. The budget had been in the can for six months. The budget for the next out-year isn't made up in August; it's made up just about the time the hearings are going on for the present. The next out-year budget is being discussed inside the Administration. Yet very few people ever take the trouble to try to influence it then.

I think a lot of Federal employees in political appointee positions would like to have input at that point. But you find it's very difficult. You go out and say, “Should we do X?” you'll suddenly get a thousand



proposals to do X. “Well, should we do Y?” A thousand proposals to do Y. You don't get the privilege of hearing the debate in a very clear way and then being able to take that into account in trying to analyze what are the realistic possibilities within the Administration. We don't try to influence the Administration enough, and we wait until it gets into the visible process in the Congress and try to influence it there, and that is getting a little late. I don't know how to fix this, but maybe Representative Brown has some ideas.

Brown: No, I don't. But I am working on the same problem myself. I don't know how to influence the process. One way I find that you can influence the out-year budget is to influence the budget you're currently working on because the OMB watches very carefully what happens this year and then they feed that back into next year.

We were just talking about raising the level of scientific literacy. There are few people who have done a better job of doing this than Leon, and few organizations better than the AAAS. It still needs to be done better. The AAAS can do a better job and we need more people like Leon who are using a portion of their great talent to assist in this kind of an effort. Really, that's one thing that can be tremendously important to us if we do it right. Because trying to create understanding among the public will allow each of those trying to do that to understand a little better themselves what they want the public to understand, and that may be the important first step.

Schmitt: I want to enlarge on what Leon said earlier about the outreach and the kinds of things he's doing. I think one of the encouraging things on the scene is, as you look around this country today, there are literally dozens and dozens and probably hundreds of local efforts being

carried out by people—by faculty at universities, by research people in industrial laboratories and so on. One that Erich and I have come across recently is a young man by the name of Dean Kamen, who turns out to be an entrepreneur who made his millions very early, and he is now undertaking the cause of making heroes of scientists and engineers.

In a program he carried out in his hometown in New Hampshire, he essentially gave teachers in the school system green stamps to reward their kids with, and these kids could then take these and redeem them, get a discount on blue jeans or pizzas or whatever. And he had a big rally at the end of the semester, and the governor was there. He has captured the kids in that community's interest in science and technology. I think there are efforts like that going on all over the place. One of the things it would be interesting to do would be to get some networking going and get some kind of an inventory to find out what really works and what doesn't work. I believe that your own kind of efforts, Leon, and the kind of this young man, Dean Kamen, are going to be a very, very important part of whatever we do.

On a different perspective here, the issue of stresses, part of the stress is internally generated, and the community itself has got to pay some attention to them. I made the comment earlier about the condition of young researchers today. We are throwing them out, requiring them to be entrepreneurs before they are really prepared to cope with that kind of an environment. So somehow we have got to change things to back off on what we've done there, I think.

Bloch: Just a point on Homer's question of where it's most appropriate or most effective to put the influence—on the Administration or on the Congress. I don't think you can tell. I think it changes from time to time, and many times it is dependent on the discipline. It's very, very important that the focus be on the totality of the process and not just a part. Too many times people think either focusing on an agency is good enough or testifying in Congress is good enough, and then they forget all about it. They thought that would have done the trick. It's the total process that is important. At any point a request can be stalled or derailed. And by the way, therein lies the

crux of the matter. To convince government about a funding action requires a major effort. It is very important that one stays the course.

Trivelpiece: Erich, I agree with you, but wouldn't you agree that the emphasis on paying attention to the Administration is less than the emphasis on paying attention to Congress? Generally speaking, we tend to wait until the budget has been submitted and then everybody rushes to the Hill.

Bloch: No, I disagree. I give you a current example. The high-performance computing initiative, for instance (PHYSICS TODAY, January, page 54), has been very much influenced by industry in discussion and dialogue with OMB over the last couple of years. How much that affected the outcome is anybody's guess. But I think it was highly effective. It was a two-pronged process. It started four years ago, in the Administration. But once it surfaced, the extra focus by industry on OMB was very, very important. And if they hadn't done that, I don't know what would have happened.

For these ideas to come to fruition takes a long time, but this extra input by industry helped, I think, and it ought to do the same in the materials area. It's not only Congress but the Administration, especially the Office of Management and Budget and the Office of Science and Technology Policy.

Goodwin: With all due respect, Mr. Bloch, there still isn't a lot of money being funneled into this program.

Bloch: What is a lot of money?

Goodwin: The kind of money either that the industry would want or that the Congress would want. There isn't any additional money.

Trivelpiece: No, but that's the political compromise within which we live.

Bloch: This year, 1992, there was an increase in that area of about \$150 million over the base, which was about \$450 million. And you will see another increase in 1993. It's growing. Not enough money? That's in the eyes of the beholder.

Lubkin: It is 12:00 noon. We promised we would stop. Is that agreeable to us all?

Lederman: We solved all the problems. [Laughter.]

Trivelpiece: Let that be the last word. ■



Brown (middle) gets a laugh from **Bloch** (left) and **Neal**.