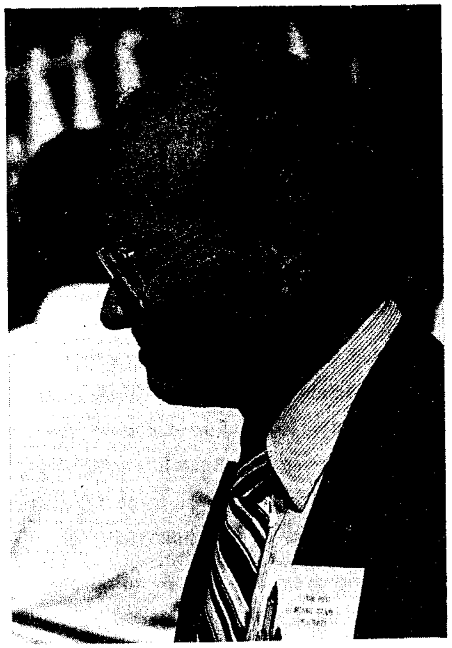

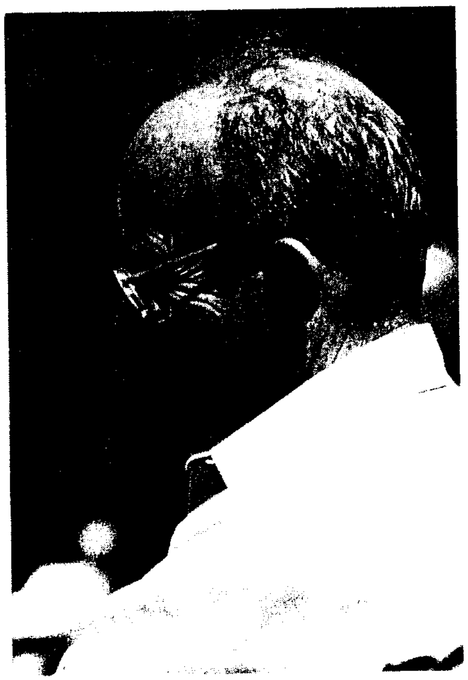

Science and Technology Policies for the 1980s

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In the 25 years or so that I have known Wolfgang Panofsky, or Pief, as he is affectionately known, this is the first occasion where we have been in the same room and I was without a jacket and he was wearing one. This must be a special occasion. It is a pleasure to participate in the Pief-Fest; it is a labor of love and a small payment on an enormous debt. I first met Pief some 25 years ago in the Eisenhower administration, working with Killian and Kistiakowsky. Those were the days of the beginnings of the nuclear test ban discussions, both domestically and in negotiations at Geneva. What a team we had: Panofsky, Bethe, Garwin, Harold Brown and others. We both served then on the President's Science Advisory Committee under John F. Kennedy, with Jerry Wiesner as chairman. As Sid Drell mentioned, that was when we achieved the partial Test Ban Treaty.

When I was Science Advisor under President Carter, Pief chaired or served on most of my committees, from MX-basing to antisatellite technology to the nuclear test ban—that eternal issue that will not go away. Now, at the National Academy of Sciences, he is a key member of what might be our most important committee—the Committee on International Security and Arms Control. For that activity, he was a key force in a very important study that dealt with the problems of communications in science and national security regulations.

I wrote down a lot of adjectives to characterize Pief, and I see that Sid Drell has used them all—scientifically honest, balanced, sensible, patient, a brilliant analyst, productive, clear-headed, strong-viewed but a consensus builder, dedicated to peace, but nonideological in the sense that ideology does not cloud his analyses of important national issues. It is inconceivable to think that Pief is retiring from intellectual pursuits or from addressing national issues and, of course, he is not. In this transition in his life, I think he will have more time to devote to these important endeavors.

I would like to talk about science, technology, and industrial policy—issues that are receiving more attention than ever before. There are many reasons for this. They have entered the public consciousness, they will be debated in the coming election, and they are on the agenda of the economic summit meeting. One of our wise men, Damon Runyon, who practiced philosophy on Broadway, once said that "The contest was not always to the fastest and the strongest, but that's the way to bet." Concerned as you are with the strength of American science and technology, all of you live Runyon's maxim every day. You know what it takes to win the contest. But getting there is another matter. I cannot provide magic maps for you, but I will try to provide some useful perspectives from where I sit.

I would like to touch on several things. One is what might be called a scientific and technological epiphany, the now intensified and wider awareness of the importance of science and technology, and how technology is actually created. Irving Shapiro, a former chairman of Dupont, once said that "Technology doesn't come from the tooth fairy." All of you have always known that; now others know it, even politicians.

Secondly, I would like to outline some directions toward which we need to go if the United States is to occupy a prominent place in the scientific and technological contests of the future. I will do that by commenting on the buzz phrase of the day, "industrial policy," and then, to make things concrete, talk about its application to something specific like big computers.

First, there is the scientific and technological epiphany that I mentioned. Perhaps the most startling proof of that was seen at the meeting of the western leaders in Williamsburg last year, when Mr. Nakasone, the Prime Minister of Japan, lectured his colleagues on recombinant DNA technology. More formally at their previous meeting at Versailles, the seven leaders asserted "that revitalization and growth of the world economy will depend to a large extent on international cooperation and the exploitation of scientific and technological development."

Underlying that statement is, I think, a quite astute realization that science and technology have changed the way the world does its business. I do not mean simply the rapidity of communications, greater access to information, and the like. I mean that nations now realize that their borders are transparent to the advances in science and the technological forces available, and that their future depends on these advances and how they will be used. Some observers have called this a new industrial revolution based on advances in science and technology. I believe they are right and that we are in the midst of it. This new industrial revolution will be dominated by or more of the following countries: the United States; Japan; Western Europe, if President Mitterand achieves his goal of uniting that part of the world; and the rising stars: the nations bordering the western Pacific—East Asia. Leadership will be based on the following: the quality of a nation's educational system; the quality of a country's science and technology base; the quality of private management decisions in spurring innovation at the level of the corporatation; and, quite important, national and governmental policies that foster technological innovation, including macro-economic policy, because interest rates, inflation, and exchange ratios will affect the abilities of any one country to innovate.

The economic viability of our country, or of any country for that matter, will depend on how it performs in this new revolution. The key to competitiveness is not solely the high technology products that the public is aware of, but it also involves the capacity for science and technology to improve manufacturing processes for developing new products and processes. Advanced technology will become a core technology knitted into the fabric of manufacturing, agriculture, processing, distribution, and, of course, the growing service industries. Although the relative contribution to our gross national product will shift from heavy industries to advanced technology and the service sectors, very important sectors like manufacturing, food production, metals, chemicals, and materials all have the potential for revitalization and increased competitiveness through the introduction of advanced technologies.

Actually, this projection is not futurism; it also can be read in the story of our past. A number of economists have studied the growth of the economy in the United States and the effects of changes in technology on productivity. E. F. Dennison, in his analysis, believes that 62% of our productivity increases is due to technology, 20% to capital, and 18% to labor. At the Brookings Institution, some economists have divided it up this way: 44% due to technological innovation, 16% to economies of scale, 12% to better resource allocation, 16% to capital, and 12% to education. So, in the past, technological innovation has been largely responsible for our gains in productivity, our growth—and that, I think, is also the story of our future.

What is advanced technology? It is a changing scene and, if I were to give this talk next year, the list of technological components probobably would be different. Of course, the list has to contain: computers and microprocessors; the ubiquitous chip for everything from sewing machines to carburetors; communications and information-processing; specialty materials; robots; computer-aided design and manufacturing; airframes and avionics in space technology; in chemistry, all sorts of advanced techniques—catalysis, laser chemistry, and others; artificial intelligence; biotechnology as it will influence industrial products; energy sources; pharmaceuticals; new crops; genetic diseases, and so on.

With the world's strongest scientific and technological base, why is there the public perception, perhaps erroneous but nevertheless the perception, that we are doing poorly in the United States? I think the public sees the importation of cars, cameras, televisions, audio equipment, and computers on an increasing scale, also sees high-quality products at very competitive prices, and wonders why all of these imports are taking place. If you look at the U. S. balance of trade figures in electronics—and you know the force that we exert in electronics in inventing and in initiating economic growth—and then look at the balance of trade in electronics for a country like Japan, you will see that we import $7 billion a year, but export only $1 billion a year. If you look at research and development productivity trends, and especially at research and development investments in the civil sector, as a proportion of gross national product, you will see that we are behind other countries like Germany and Japan. Productivity gains, capital investments per worker, unit labor costs—all of these show the United States in second or third position. The public knows these figures and is concerned.

Management's self-image at the end of the 1970s was not very optimistic. In a survey of the Fortune top 1,000 companies, 2,000 executives were asked a number of questions, including: What are your major business concerns of the next decade? They listed productivity, energy costs, new product development, and rapidly changing technology. What will be the most important influences in the 1980s on United States business? Technological change and economic regulation. Who are your greatest competitors? Japan and West Germany. What are the problems of technology and American business? Underfunding of research and development by short-term-oriented managers; a lack of understanding of technological change by top management; and a lack of technological input to the corporate management process. What are the major barriers to integrating technology in your company? The failure to involve technologically trained personnel in the planning process, and management's short-term, profit-oriented perspectives. Now, that survey was taken only about four years ago. If it were taken today, it would elicit answers that are almost entirely different. I believe that profound change has taken place in our country, and that we are addressing all of these issues. I will come back to that.

In talking about technological innovation, one has to break it up and see how we are doing with each of the components. Let us start with research and development, and then we will take up manufacturing, commercialization, and so on.

In research, we are in a golden age for American science. It is unprecedented that in such a large number of fields we have brilliant theories (you have just heard about one—extraordinary instrumental advances) and all sorts of new paradigms. In the past, it was the golden age for physics, or chemistry, or mathematics, one at a time. Now, the extraordinary times in which we are living allow us to witness golden ages for ten fields, all going on simultaneously. The United States excels in just about every one of these fields. We have solid institutions; the research university is unique in the world. We also have good government support. The underwriting of science is no longer political; it is apolitical, and everybody agrees that that is a good thing. So, in research, we are doing very well. In development, which depends upon the transfer of this new knowledge to industry, we have problems, but no country does it any better. The links between our universities and industry are extraordinary. The consultant professor is uniquely an American phenomenon and we have the transfer of technology in both directions because of that relationship. So, with regard to research and development, this nation is clearly in the winner's circle.

Going back to the several fields in which we are enjoying a golden age, I can cite a number of examples about which I shall not go into detail; they are described in a series of National Academy of Sciences' reports called "Research Briefings." I commend them to you. In one hour and a 20-page paper, you can learn—in language that laymen can understand—about the great progress in immunology, neurophysiology, agriculture, computers, artificial intelligence, physics, chemistry, atmospheric sciences, and astrophysics. These briefings are extraordinary statements that will demonstrate to you the unprecedented times in which we live.

Let us return to the innovation process. I have talked about research and development and how we are doing very well there; we are the envy of the world. When it comes to manufacturing, I think it is generally recognized that we had problems in the decade of the 1970s that are just beginning to be addressed. Manufacturing is the weakest link in the overall production system in the United States. This is where Japan is the envy of the world. Our production costs are too high; we have problems with quality control; innovation is too little and it has come too late. What we need in the United States is a corporate culture that embraces the concept of low-cost production based on research, development, and modern engineering. This can happen even in mature industries: witness radial tires which the French pioneered, high-speed trains in Japan, the plate glass and paper industries in which we performed superbly because of the introduction of advanced techniques. Then, of course, we need our engineering schools to train engineers who know something about manufacturing, a field they left behind some decades ago. All of these things are beginning to happen in our country and I will say more about that shortly.

Now, I would like to make some observations about industrial policy. The tidal changes that I spoke of in science and technology are causing national stresses. The industrialized economies are being forced to create new strategies. Japan has done it consciously. West Germany, France, and the other European nations are trying to follow suit and, if Mitterand's vision of aggregating Western Europe in research, science, technology and investment is brought into being, I think that these countries will become very important competitors as well—and that is a good thing. We are progressing in this direction, but without any overlay of state planning. We are, as is our national style, doing it messily. But we are doing it. The point is that the deficiencies we now see that I have mentioned and the weaknesses of many of our industries, in changing employment patterns and so forth, reflect a deep global change born of the bonanza of the new technologies as exemplified by integrated circuits.

Moreover, the pace of technological change is quickening. Five years ago, no one had heard of expert systems. They are now on the verge of becoming a major industry—the technology of knowledge, if you will. Less than 10 years ago, monoclonal antibodies were only dreamed of. Now it appears that they may well become, within the next year or two, a billion dollar industry in the United States. Ten years ago, molecular beam epitaxy, a technique for atom-by-atom layering of semiconductors, was basic science. Today it is used in manufacturing. The rapidity of technological change couples to the fact that purely domestic businesses are increasingly anachronistic. A multiplicity of forces has created world markets. These forces have made a fluid, global, economic system. Investments of American corporations abroad totaled $227 billion in 1981. A United States company selling small computers gets its printers from Japan and its monitors from Taiwan. The notion of a world market is slowly infusing our national consciousness. Nevertheless, I think we will be troubled for a long time by the fact that, while markets are now global, our politics and our policies remain largely rooted in the national mode.

Yet, there is under way the consciousness-raising that I alluded to earlier. A string of reports from government, from my own institution, and from the universities iterate the complexities of technological innovation: how difficult it is, and how different it is from the way that science is done. We are learning again—slowly—that ideas, namely science, are the cheapest part, that they should be supported, and that even development, while more expensive, is not sufficient. Development means being able to make one of something, but the problem, as you well know, is to make lots of something, and to do it better, cheaper, and faster than your competitors. And, even when you have done that, you can fall flat if you cannot sell it. Being first with a product is not enough; we can tick off the companies that made the first home computers, or the first hand-held calculators. Many of these companies are gone now—not because they did not have a good product but because they could not market it. The pioneers are the ones with arrows in their back, and that is true in science as well as in industry, I suppose.

Much thought is being given to how we achieve technological creation. What is unique about the American experience that led us to technological and scientific supremacy? Have we and the world changed so much that the way we once operated no longer works? How did we do it?

For one, it was part of our national birthright. Benjamin Franklin, and Thomas Jefferson, between them, could have kept the patent office busy for many years. We apparently had in our national genes a predisposition to invent things that were practical and commercial. Secondly, Thomas Edison, Henry Ford, and Alfred Sloan taught us how to convert new knowledge into salable things. Edison really invented the modern, developmental laboratory; that is, he created a place where technologically trained people systematically explored how to apply new knowledge to practical things of commercial value. Henry Ford taught us what we know about manufacturing technology; he taught us how to make complicated things well, abundantly, and cheaper than anyone else. He also taught us a few lessons about marketing. Alfred Sloan created the first modern technological corporation. There were others, such as Cecil Green at Texas Instruments and Thomas Watson in computers. You can name your favorite example. The nation has been blessed by intellectual descendents of Franklin and Jefferson who, in common, were able to combine their visions with the hard work of getting them realized.

What Edison and the others gave us was converted into American technological supremacy by three forces, all owing to World War II. Because they were persecuted, we gained some of the best European scientists and engineers. They, with our native scientists, created the most powerful cadre of the very best technological talent with which any country has ever been blessed. A second force was the massive government entry into the support of scientific and technological development. There were created in short order the Aeronautical Laboratory at the California Institute of Technology, the Radiation Laboratory at the Massachusetts Institute of Technology, the Radio Research Laboratory at Harvard University, and the other national laboratories that brought together the nation's native and émigré talents to work on the deepest kinds of technological problems. Finally, the scientists who worked in these laboratories, tempered in the white heat of war, became in peacetime the faculty that trained you and me. It was this new generation that drove the United States to scientific and technological supremacy. It created the materials revolution, the electronics and computer revolutions, the biotechnology revolution—and all of this occurred within a fertile setting. The United States created a research system that is almost unique in the world. It is rooted largely in the university.

Scientists and engineers working in industrial technology were ready to receive the new knowledge generated in basic research and to convert it to new processes and products. The consequence was an incredibly flexible, productive research and development enterprise—the best in the world. Another element in our success was the financial setting. It was a rich one for entrepreneurial risk-takers. Let me illustrate that. The United States created the microelectronics revolution but, as Bill Perry once pointed out, it was a Britisher named G. W. A. Dummer who, in 1952, first had the idea of an integrated circuit and outlined what it should do. In fact, as you know, the integrated circuit was invented after that by Jack Kilby, of Texas Instruments, and Bob Noyce, of Intel. Years later, and I am indebted to Perry for this quote, Dummer gave his reasons why the integrated circuit was born in the United States and not Britain. It is worth remembering, he said, that the giant electronic companies were formed after the war by relatively few, enterprising electronic engineers setting up on their own, either with their own capital or risk capital from individuals or a bank. Dummer added that often a government contract would start them off; hard work was necessary, he said, and the large home market was a great asset. But the climate of innovation was such that virtually any advanced technological product could be sold.

The financial climate that made this possible was enhanced by a boom in the stock market, unleashing a rich source of equity capital. It made possible the plentiful supply of venture capital needed to create the industries of Route 128 and Silicon Valley. We also had the right cultural climate, one that encouraged the entrepreneurial spirit. This spirit was exemplified by people like Bill Hewlett, Dave Packard, and Bob Noyce—and the others who created giant companies out of their ideas, their drive, and their ability to capture the necessary finances. That was the atmosphere in which we created great new industries—the climate in which we came to dominate every single technological sector.

As you well know, we stumbled badly in the 1970s and you also know the reasons. There was the drain of the Vietnam war on our spirit, technical manpower, and funds. We short-changed basic research. A succession of companies closed down or gutted their research laboratories. Changes in the tax code cut into the availability of venture capital. Companies, in retrospect, can be seen as having made some bad decisions. In many companies, financial factors came to dominate internal investment decisions. Corporate time horizons compressed and the hurdles for investment decisions multiplied. In all, financial reporting and control systems tended to emphasize the near term, the sure thing, the predictable, and the quantifiable. Those were the bleak '70s and, as I said before, I submit that stage is behind us.

As I also said earlier, there is the realization at all levels of our society, including the White House, of what technological innovation is really about: how important it is to the country, the climate in which it thrives, and how difficult the process actually *is*. Further, I believe we are now seeing an upwelling of forces, growing out of the highly flexible and unique structure of the American technological enterprise. Putting it another way, we are seeing a gathering of the forces of the technological industrial revolution that I mentioned earlier. And that is occurring in the United States in the very absence of any formal mechanisms for state planning, such as Japan has in its Ministry of International Trade and Industry.

What are these forces? They include increasing expenditures by U.S. industrial enterprise on their own research and development. This investment now exceeds that of the United States government. Also, there is white hot concern with the failing grades that American education is receiving, especially in the teaching of science and mathematics. Another potent factor is the real growth in the federal budget for basic research. A fourth element is the explosive growth, especially in the last four years, of the venture capital market. Fifth is increased attention to the damage that may be done to the innovation process by some governmental policies. A sixth trend is the formation of unique industrial research ventures—for example, the Microelectronics and Computer Technologies Corporation, a joint venture of about a dozen companies working together for the first time. Seventh, there are the multiplying links between universities and industry; which the Semiconductor Research Cooperative and the Stanford Microelectronics Facility are excellent examples.

I have tried to sketch the national and international scene following World War II and to show the various forces that were responsible for the amazing postwar growth of American science and technology, for the bleak period of the 1970s and now for this new national realization that we did make some mistakes and must do the things necessary to correct them. I believe that in this country a middle course of industrial policy is emerging. On the one extreme, the laissez-faire approach, based on the attitude that the government has no role, is in a sense a mirage. That position is just not tenable in the United States—or anywhere else in the world. The other extreme of industrial policy—namely, government involvement, with the government picking the winners—is not in our traditions. It is not our custom and, where we have tried to adopt such an approach, it has not worked; we have made disastrous mistakes along the road. I think a middle course of thought and action is emerging in this country—a recognition that the government should provide a nourishing climate for innovation, but that it should not try to determine the outcomes. That middle course has several subthemes, of course: vigorous new investment in education and in research, and an awareness that government economic policy will affect our abilities in the years ahead. As a quick example, if a company succeeds in increasing its productivity by 10%, and that is a lot for mature industries, it can be wiped out simply by an increase of 10% in the dollar/yen ratio. So we must recognize that economic policy is a key element in determining how well we will do.

Let me sum at this point. In the last two years, we have gone through national agonizing about our national strength and will, our ability to innovate, and our fitness to compete in the global climate, and we are emerging stronger. We now can acknowledge some of the apparent contradictions in our style, namely, that our research and development system is messy, but that it is also incredibly flexible, quick to exploit new ideas, and driven to excellence. It needs resources, and we are supplying them. It needs tender care and I think we are providing that now.

Industry is changing; it has profited from its mistakes in the sense that there is a new class of managers coming into control—managers with technical sensitivity. They may not be technical managers, but they are at least sensitive to the technological revolution that is taking place around them. With these resources that I have mentioned and with these changes, I think we will be competing very successfully with other industrialized countries. There are so many opportunities: recombinant DNA, chips, robotics, fiber optics, drugs, chemicals, and aircraft. Each country in the global marketplace is seeking leverage for its unique capabilities, and that is only fair. Sometimes, we may not like the way they do it, and sometimes we have not played fairly. Someday, we can hope, all of us will recognize that it need not be a zero sum game. However, it is the quality of our nation's science and technology and our ability to use them that will determine, in large measure, how we do. That is illustrated by a story that applies to science and the way it is done as well as to our national economic issues.

There were two hikers who met a very angry bear. The bear growled and it was obvious that he was about to charge. One fellow said, "What are we going to do? He's going to kill us." The other fellow reached into his knapsack for his running shoes and put them on. "You can't outrun the bear," his partner said. "No, all I have to do is outrun you." Well, the story applies to particle physics and to national issues. I leave it to you to decide who is the bear and who puts on the running shoes.

Thank you.