R & D in the United States: Its Strengths and Challenges

Ian M. Ross

Summary. The promise of technology for improving the quality of life has never been greater, and American science and technology has led the way toward fulfillment of that promise. Now this preeminence is threatened by forces that may affect technological progress throughout the world. It is up to those of us in science, industry, and government to strengthen the institutions that have made us the leaders and to restore our initiative.

These are exciting and challenging times for science and technology. Our society is poised, we are told, at the threshold of the Information Age, a time when the promise of technology has never been greater for raising productivity, improving the standard of living, and changing for the better the quality of life itself. We who are in American science and technology can be particularly proud of our world leadership in the total innovation process. But there are considerable concerns today that we could lose our preeminence. This article will examine the causes of these concerns and suggest some actions that may help preserve and enhance our leadership.

It may be useful first to examine how the United States achieved preeminence in science—a relatively recent state of affairs in terms of human history. Fifty years ago it would have been rash to suggest that the United States would eclipse the European scientific establishment. Until 1930 the United States was in effect a scientific backwater. Before then, if you were an American physicist, you would have gone to Europe to get your Ph.D. But shortly before World War II, and especially immediately thereafter, the flow changed in the other direction. Many of the early physicists came to America to avoid persecution in their homelands, but many others came looking for a climate that would support and satisfy their creativity. Only 17 American scientists received Nobel prizes during the first 40 years that these prizes were awarded; by contrast, there were 117 Nobel laureates in science from the United States in the second 40 years—more than from all the rest of the world combined. Other evidence from technology and engineering illustrates that although the United States is leading the world in science and technology, our period of leadership has been brief.

What is it, over the last four or five decades, that has caused science and technology to flourish? I see four principal factors. The first has been a stable, vigorous economy and, over most of this time, a low inflation rate. Our economy has sustained the idea that a belief in the future would pay off; it has demonstrated the fact that investment in new ideas and products could yield a great return.

Second, we have had abundant natural resources. Over most of this time the nation has been largely self-sufficient in materials and in energy. We have had a rich agricultural sector, skillfully managed by a relatively small portion of the population, thus freeing the majority of people for other innovative enterprises. Such abundance helped provide a sound balance of payments, which is a foundation for a strong economy.

Third, we have had free competition among ideas—the kind of competition that allows the best ideas to come to the surface unrestricted by political orthodoxy or social position. Quite simply, it has been acceptable in this country to hold and to discuss unpopular ideas. We have had the assurance that good ideas and hard work will be rewarded.

Fourth, we have had a healthy balance of cooperation and competition among three of our major institutions—government, the universities, and industry. I shall expand on this last statement, because I think these three institutions, working together, are critical to a productive future. Starting with government, our stable, democratic system has not tried to over-control us. Regarding science, government seems to be at its best when it stimulates cooperation among the other institutions. Something that may not be widely known is that for the first few months after the invention of the transistor, serious consideration was given to classifying the device. There was an obvious temptation to preserve it as a national defense resource. After intense debate, however, the decision was not to classify the transistor, but rather to stimulate cooperation and competition in its development. This is what led to the industry of which we are so proud today. It is powerful to contemplate what might have happened had a less wise government made a different decision.

Another example of cooperative work leading to success can be found in the space program. The manned space flight program, at its height, involved one-quarter of a million people—most of them in industry, some in universities, and a few in government. But the overall program was brought together by a government stimulating cooperation among all three institutions.

Turning to the universities, clearly their major asset is freedom of thought and freedom of expression—a complete lack of the oppressive structure seen in many overseas academic institutions. This freedom has led not only to the great research output of our universities, but also to the high quality of their graduates. We hear concerns today that the technical graduates of our universities may not be as good as they should be. In my business we are very large employers of people coming straight from college into the technical arena. Let me assure you that what we find today is what we have found in the past: The best students coming out of the universities are indeed excellent.

The third institution on which we have relied is industry. Our industrial sector has been financially strong, and able and willing to invest in long-term research. At its best, industry supports the total innovation process, for industry combines research, development, manufacturing, and interaction with the ultimate user. The total process is not complete until use is made of a new idea.

Thus, America over the last 50 years or so has had four basic ingredients of scientific and technological preeminence—a strong economy, abundant resources, freedom of thought, and strong institutions. The interactions among these ingredients, has been synergistic. A strong

The author is president of Bell Laboratories, Murray Hill, New Jersey 07974. This article is adapted from a lecture delivered on 4 January 1982 at the AAAS Annual Meeting, Washington, D.C.

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economy, for instance, fuels growth in technology, and technological growth then further stimulates the economy. Together, such interactions created a pioneer mentality in American science and technology, and a tradition of the technical entrepreneur—started by the Fords, the Edisons, and the Bells, and inherited by the pioneers of instant photography, computers, Xerography, and, more recently, by the microelectronic miracle workers of Silicon Valley and elsewhere.

Today, however, there is much concern that America's preeminence, so recently gained, may be threatened. There are real causes for such concern. The first is the current high inflation rate, which discourages risking investment for long-term payoff. This is a very serious concern for R & D, because R & D is an inherently risky endeavor, and payoff frequently takes a long time. An informal study at Bell Laboratories of the innovation cycle for some basic breakthroughs such as the transistor, the LED (light emitting diode), and the laser showed that the period from the first basic work to real applications is typically 10 to 20 years. Today, the risk of R & D is actually increasing because of ever-increasing expense. Most of the inexpensive things have been done. Today, good R & D often requires large teams, costly equipment, and huge capital investments. To appreciate that, one can look at such examples as silicon VLSI (very large-scale integration), high-energy physics, and nuclear fusion. With today's high inflation rates the payoff must be enormous to justify long-term investments with such risks.

A second concern is the current national obsession with short-term results. You frequently hear about the tyranny of the quarterly report, and about chasing the "fast buck." This activity leads to the search for incremental improvements rather than fundamental advances.

Third, there appears to be a declining respect for the quality and inherent value of products. If you look at the countries that have led in international trade, you will find that every one of them has been known for the quality and value of its products.

Fourth, we appear to be suffering from a lack of public understanding of modern technology itself. Technology is playing an ever more intimate role in people's lives, but it, and its potential applications, are much harder to understand than ever before. If you think back to the invention and development of the telephone, the electric light, the airplane, and other advances, it is obvious that these were relatively simple to understand. They met well-identified human needs and were not perceived as significant threats to our social fabric. Now compare such inventions to today's microelectronic miracles, where the smallest elements are approaching the size of a wavelength of light. Think of computers, nuclear power, genetic engineering. These are difficult to understand. Many of their potential uses are not widely apparent. Indeed, there is growing distrust of such technology because of this lack of understanding. Look at the Information Age we are entering. Already we hear concerns that the Information Age may be a threat to privacy, that the proliferation of computers may be a threat to job security. Many such fears are the result simply of a lack of information and understanding. It would indeed be ironic if the much-heralded Information Age should fall prey to an information gap!

All of these concerns about our continuing technological preeminence lead me to a much broader concern: If the United States loses R & D initiative, if we fail to capitalize on the tremendous opportunities still available to us, then technological progress may well slow down all over the world. The United States in a very real sense has been the engine driving worldwide scientific progress. We have had a unique combination of fundamental innovation, research leadership, and willingness to share the results throughout the world. When I look abroad I do not see the same fertile ground. Nor do I see a different environment for innovation as an alternative to the one I have been describing. Thus if the United States loses its scientific initiative, my concern is not that some other nation will fill this role in our place, but that no other nation will fill this role, or at least not as well.

Thus there are good reasons for concern about America's preeminence in science and technology. So what should we do? Here are five suggestions. First, and most critically, we must look to government to help straighten out the economy. The best thing for R & D today is a healthy economy with a low inflation rate.

Second, stimulated by government, we in industry must take a longer-range view. We must be willing to take more risks. We must support R & D that yields fundamental advances in addition to R & D that yields short-term benefits. That, of course, requires consistent, long-term financial support protected from the ups and downs in the economy.

Third, the universities and industry must seek solutions to the problems created by the recent, rather precipitous reductions in government R & D support. In my view, the concern here is not so much the reductions in government spending, but their rapidity. Some years back, before the massive infusion of federal support, there was a balance between public and private support of the universities. We now have to seek a new balance. Both government and the universities must realize that this will take time, and that industry cannot solve the problem by providing one dollar to replace each government dollar. We must find ways other than the simple substitution of a dollar for a dollar.

Fourth, we in the scientific community have an obligation to make our work and goals understood by the public and the government. Only then can the public make the right decisions on the massive amounts of investment needed in R & D; only then will the public be prepared to accept rather than reject the ultimate results of technological innovation. At the same time, we in the scientific community have another obligation: to understand the needs of society in order to make sure that what we produce does in fact meet a real need and will be accepted.

Finally, we need to do a better job of setting national priorities in science to assure that our limited resources are allocated wisely and effectively. Several decades ago, when R & D was not as expensive, when resources were not as precious, we could get by very well without careful priority-setting. We can not afford that today. Of course, priorities are set each time the government makes an appropriation, but those are frequently priorities within a given field. However well they are set, they do not solve the problem of national priorities. I believe no rational process exists for setting these priorities. What we need is a cooperative, interdisciplinary examination of national technical goals. Working as partners, the scientific community and government must assess performance versus needs and opportunities. We need to establish a forum—not binding, not overriding—but a forum to explore the scientific priorities of the nation.

Conclusion. As I said at the outset, we stand at the threshold of the Information Age. The promise of technology has never been greater. But our ability to lead in fulfilling that promise faces serious challenges. To meet these challenges we must build on our own unique strengths—our freedom of ideas, and our strong, cooperative yet competitive institutions. We must rebuild a shared sense of optimism that we can shape the future for the better. Above all, we must resist the temptation to emulate others. We should simply do what we know how to do, and do it well.