

## **THE ROLE OF RESEARCH IN THE UNIVERSITY OF THE FUTURE**

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I want to begin by saying what a great pleasure it is to be back again in Japan. My first trip to this beautiful country took place in 1970, when I participated in a conference on computer-based instruction and was fortunate enough to be a guest at several Japanese universities. When I served as director of the National Science Foundation from 1975-1980, I traveled to Japan often for discussions related to science policy and research exchanges between our two countries. I have always found much to learn and much to admire during my visits over the years. I have been especially impressed by the energy and skill of the Japanese people, which have contributed so critically to the leadership role Japan now plays in Asia and indeed throughout the world.

It was Professor Akimasa Mitsuta who first introduced me to issues relating to science and education in Japan. I have had the pleasure of knowing Professor Mitsuta for almost three decades and have frequently sought his advice on a number of topics, including international education. More recently, he has been an invaluable adviser to the Graduate School of International Relations and Pacific Studies at the San Diego campus of the University of California and to international programs throughout the University of California system. I owe him a great personal and professional debt for the experience, wisdom, and friendship he has so generously shared with me over many years.

I deeply appreciate the gracious invitation from the Ministry of Education, Science, Sports and Culture to visit Japan and discuss science and higher education issues with you. I am interested in reviewing these issues because they are relevant to discussions going on both in the United States and in Japan today. One of the most dramatic changes I have observed in the Japan of the 1990s is the interest among government and education officials alike in building a strong foundation of basic research to ensure Japan's future economic competitiveness. I believe there is considerable wisdom in this approach. It is one that has been used in the United States for some 50 years, with great success. How this approach evolved, and the role

universities play in spurring American economic growth, are the principal themes of this lecture.

In my judgment, the economic evidence about the relationship between research and development (R&D) and American economic growth is overwhelming. As late as the mid-1970s, there was no substantial economic data, no reliable economic analysis of the relationship between investments in R&D and economic development. When I served as director of the National Science Foundation in the late 1970s, we were well aware of the lack of such economic data in making the case to the Congress for federal support of research, and of the gaps in our knowledge about how R&D affected economic growth. Accordingly, we initiated a special research program at NSF focused on just that issue--the relationship between investments in R&D and the growth of the American economy. In the intervening 25 years, a substantial body of research has been conducted, which has in turn led to a development in economics called "new growth theory." This work was nicely summarized in a recent report of President Clinton's Council of Economic Advisers: 50% of the growth in the American economy in the last 40 years has been due to investments in research and development. Obviously, the private sector is a major driver of R&D, but federally funded research at universities throughout the United States also plays a key role. The report points out that when federal investments in university research increase, there is--with an appropriate time lag--a corresponding increase in private-sector investments. There is now a well-researched link between university-based research and industries' R&D efforts.

The State of California provides one of the best examples of this linkage. In the early 1990s, the state endured one of the worst recessions in its history. California in prior periods had entered recessions later, and come out much earlier, than the rest of the United States. But in the 1990s this traditional pattern broke down. California suffered a brutal economic downturn fueled by tremendous cutbacks in defense and aerospace--a huge loss of jobs that resulted in a dramatic drop in the tax revenues of the state. California's economic hard times, I might add, had a direct and painful impact on the University of California. UC's budget from the State of California is about one-third less today than it would have been if the State government had been able to provide only normal cost increases--in other words, a barebones budget--in the early 1990s. This staggering

figure equals the entire 1995 State-funded budget for three of UC's nine campuses.

What has happened in the past few years? California has come storming back from the recession. Why? New jobs have been created at a fast rate. Where are those jobs coming from? From a particular type of activity: high technology. And these high-tech enterprises are not the vast IBMs and AT&Ts of the world. The companies that pulled California out of recession are small, entrepreneurial, high-tech ventures. These companies (and their technologies) can be traced directly to the research universities of California, both public and private. And by that I mean the nine campuses of the University of California, the California Institute of Technology, Stanford University, and the University of Southern California.

Biotechnology, for example, a booming industry in California, traces its success--in fact its very existence--to research programs that came out of the state's universities. Digital telecommunications is another case in point. It could not exist at its current scale and scope without the California universities that produce the research and educate the engineers and scientists essential to keeping this industry on the cutting edge. Multimedia, computers, and software are yet other examples.

Both new growth theory and our recent experience in California make it clear that research and graduate training will play an increasingly important part in ensuring the economic growth on which our standard of living depends. The University of California is very much focused on its responsibilities to help keep the California economy thriving and productive. During this past year, for example, the University of California held a statewide conference on technology transfer, bringing people from the University together with colleagues in government and in industry to examine how we can do more to facilitate the transfer of technology. We have also established a new program at the University of California--the Industry-University Cooperative Research program--which seeks to identify the most promising research areas for new products that, in turn, create new jobs.

Let me explain briefly how the Industry-University Cooperative Research program works. A UC researcher joins with a scientist or

engineer from a private company to formulate a research proposal. A panel of experts drawn from industry and academia selects the best projects for funding. At least half of the funding for each project comes from industry, with the remainder from the University.

The benefits to companies and to California are evident. The most important of these benefits is that the UC program involves graduate students in every aspect of the research it sponsors. Industry thus gets the benefit of some of the world's brightest young minds. Graduate students learn firsthand about industry's needs. As a result, they have an incentive to stay in California and continue contributing their talents to our economy.

And because the Industry-University Cooperative Research program targets specific, next-generation research in areas of California's greatest strengths and opportunity, it is a significant element in the state's strategy for maintaining its economic leadership.

There is growing interest in programs like these not only in California but in other American states as well. The impetus to greater linkages between universities and industry grows out of a longstanding American belief that universities should not be divorced, but on the contrary, deeply involved in helping solve society's problems. But there is another reason for this phenomenon as well. The United States is unusual--even unique--in the degree to which it relies on universities to perform basic research. The roots of this phenomenon reach back 50 years in our history, to the end of World War II. Near the end of the war, President Roosevelt turned to his science advisor, Vannevar Bush, for advice about the future of American science. Vannevar Bush is one of the great individuals in U.S. history, insufficiently known and honored for his towering contributions as a statesman of American science. His report, which appeared shortly after President Roosevelt's death, was entitled "Science: The Endless Frontier." As the title suggests, Bush viewed science as a vast frontier of opportunities to serve virtually every aspect of the national welfare. His report is one of the great documents in American history because it set the stage for the modern era of science and technology in the United States.

What were the arguments that Vannevar Bush put forward? First of all, he asked "Who should fund the research and development effort of the United States?" Let me make a few distinctions here.

For simplicity of expression, I will use the terms basic research, applied research, and development. Basic research is not focused on applications; the term "curiosity research" is sometimes used to describe it. It is driven by a sheer interest in the phenomena rather than potential applications. But at a certain point, basic research may reach the stage where there is potential for application and accordingly a need for applied research. Next it moves into the development stage, involving the creation of new products and processes. Bush argued that applied research and development should be done by the private sector, by industry. But he also argued that the private sector would not provide an adequate investment of funds in basic research. In essence, he argued that private market mechanisms ensured that industry would invest in applied research and development, but would not ensure adequate investment in basic research. His argument, which has been well supported by subsequent economic research, was that an investment in basic research by a particular company could often generate results that were just as valuable to a competitor company as to the company making the investment. There was no question about the societal returns for basic research, but there was not the same return to the specific company making the investment. Thus, he argued that the funding of basic research was an obligation of the federal government.

The second question he asked was "Who should perform R&D activities?" Applied research and development, he said, is a private sector responsibility; the private sector should perform that kind of activity. Who should perform basic research? The former Soviet Union carried out research in institutes run by the central government. The French have the centrally administered CNRS programs. The Bush concept, based on the experiences of World War II, was that American universities should be the principal performers of basic research; and that the federal government should provide the funds for that work.

Then there was a third part to Bush's analysis. He argued that basic research should be funded through a peer review process. Individual scientists should make proposals for work they thought was valuable. A group of peers--leading scientists from around the country--should evaluate these proposals and decide which to fund and which not to fund.

Federal science agencies in the United States do not provide unrestricted block-grant funding to universities. Rather, individual scientists submit proposals that request funding for specific research projects. A scientist's proposal is then sent to other scientists for their evaluation. This evaluation--the peer review--is the critical factor in ensuring that the best science is funded.

Those were Bush's arguments: The federal government should fund basic research, while applied research and development were the responsibility of the private sector; basic research should be performed in universities; and this basic research should be funded by the federal government through a peer-review process. The Bush model created a sea-change for American universities. Before World War II, universities were peripheral to the R&D enterprise of the United States. Today they are at the center of American research activities, thanks in large measure to an extraordinarily successful partnership with the federal government. As a result, both the research enterprise itself and the U.S. economy have prospered. I do not believe it is an overstatement to say that when the history of the last half of the twentieth century is written, the vital role research universities have played in the American economy will be regarded as one of our greatest accomplishments.

In recent years, there has been much discussion in the United States about the need for a new national science policy, on the premise that Bush's 50-year-old vision cannot provide a blueprint for the twenty-first century. It is true that some of the arguments in Bush's report are now questionable, some of the issues he considered important of interest only to students of the period. What remains pertinent is his vision of the role of government in research, including his assertion that the federal government has both the authority and the obligation to support basic research. More boldly, by arguing for the primacy of basic research supported according to norms set by scientists themselves, Bush implicitly asserted that universities defined the U.S. research enterprise. Bush gave them pride of place at the center because, as he argued, they had the potential to energize the entire system.

But federal investment in R&D is likely to decline as the United States government struggles to balance its budget. The President of the United States and the Congress have reaffirmed their commitment to

balance the federal budget by the year 2002. Although some of the predictions about draconian cuts in federal funding have not so far materialized, this remains a matter of concern to research universities throughout the nation.

The potential erosion of federal support for academic research is worrisome precisely because of the central role universities play in the overall R&D effort. Could industry take their place as the vital center of the American research enterprise? The evidence suggests not. As recently as a decade ago, several large U.S. firms performed significant basic research in their own corporate laboratories. Today, virtually all industrial research focuses on the solution of specific problems, often by building on the results of university research. AT&T has essentially pulled out of basic research and so has IBM; both companies have come to the view that they are just not big enough and wealthy enough to support basic research. In the United States we are relying more than ever on universities for the basic research that will ultimately fuel our economy. A recent statistic sums it up: Seventy-three percent of the papers cited by U.S. industry patents are based on publicly supported science, authored principally by academic scientists; only 27 percent are authored by industrial scientists.

I am more optimistic than many of my colleagues that the federal government will find a way to continue funding university research at a reasonable level. It is my view that from a political perspective, most people in the United States who have thought about these issues-- Democrats and Republicans alike--have concluded that support of our research enterprise is critical to the national interest, and therefore sound federal policy.

In its simplicity and flexibility, Bush's report remains a model for science policy. But does Bush's model have any relevance for contemporary Japan? I believe it does. The July 1996 Basic Plan on Science and Technology commits the Japanese government to double its R&D investments during the next five years, emphasizes the promotion of basic research, and proposes specific steps--such as improving education and research in graduate schools--to integrate universities more effectively into Japan's research system. I can think of no better way to invest in the Japan's future economic leadership, and I congratulate you on this farsighted policy.

Obviously, no model can be imported wholesale from one country into another. Japan is finding its own way and its own solutions to the challenge, increasingly recognized by governments around the world, of putting knowledge to work in the economy. But however solutions differ, I believe that more and more nations are coming to the realization that their universities are priceless sources of ideas that can create jobs, give birth to new industries, and stimulate the productivity growth that will enable them to create a better life for their people.

We are living in one of the most productive eras of intellectual discovery in history. From agriculture to medicine, from aerospace to computing, many fields of science are experiencing a series of revolutions that are remaking our ideas of what is possible. These revolutions are occurring on the campuses and laboratories of research universities every day. We have only just begun to tap the possibilities of this explosion of knowledge, and the effort to link intellectual discovery more closely to applications has major implications for economies around the world. Universities are key to this effort.

Let me conclude by pointing out that in the United States, the nation's most distinguished research universities are members of an organization called the Association of American Universities. The AAU includes 62 universities--not a large number in comparison with the 3,700 institutions that make up the American higher education system. (It should be noted that six of the AAU institutions are campuses of the University of California.) But, for reasons I have explored in this paper, these 62 institutions have an impact on America's prospects far out of proportion to their numbers. In a world in which scientific knowledge doubles every 12 to 15 years, research universities are clearly an important element in any nation's economic strategy. And impressive as their past accomplishments have been, the possibilities are so plentiful, and the potential is so enormous, that in my judgment the most exciting days for research universities lie not behind us but ahead.