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RESEARCH UNIVERSITIES AND THE NATION'S ECONOMY

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In 1958 the citizens of San Diego voted to give public land to The Regents of the University of California for a new research university in La Jolla. The ballot statement in favor of this land conveyance stated:

“The coming of the university will also bring great economic benefit to San Diego because...the basic scientific research and teaching which will be the core of the campus will help enlist and retain scientific and technical specialists for our existing industries and will bring many new research industries to San Diego.”

From its beginnings, UCSD has evolved into one of the nation's premier research universities. And in the process has fulfilled the ballot statement's promise that a research university would strengthen the economy of the San Diego region and spawn many new companies.

By the term “research university” I simply mean an institution that has undergraduate education at the core of its mission, but in addition places a special emphasis on faculty research and graduate education at the Ph.D. level. The major research universities in the United States are members of the Association of American Universities¹ which includes 62 institutions; not a large number in comparison to the over 3,500 colleges and universities that make up the American higher education system. But these 62 institutions have an impact on our nation's prospects far out of proportion to their numbers. In a world in which scientific knowledge doubles every decade, research universities are a critical element in the American economy.

I should note that of the 62 universities in the Association of American Universities, nine are located in California. Three are private universities—Cal Tech, Stanford, and USC. The other six are campuses of the University of California—Berkeley, UCLA, UCSD, UC Santa Barbara, UC Davis, and UC Irvine. No other state comes close in having the number of research universities that are located in California.

The evidence for the relationship of a research university to economic growth is overwhelming. The case is nicely summarized in a report by the Council of Economic Advisors to the president of the United States.² About fifty percent of American economic growth since World War II has been the result of investments in research and development (R&D). Obviously, the private sector is a major driver of R&D activity. However, federally funded basic research at universities plays a key role, and acts as a powerful catalyst on the nation's total R&D effort. The Council's report points out that when federal investments in university research increases, there is—with an expected time delay—a corresponding increase in private sector R&D investments. There is now a well-documented link between university-based research and industry's R&D efforts. And, of course, those universities that lead in research have a powerful impact on their regional economies.

The United States is unusual, if not unique, among nations in the degree to which it relies on universities to perform research. The roots of this phenomenon reach back to World War II. During the war, American science made major contributions. The atomic bomb, high-frequency radar, proximity fuses, sonar, cryptography and antimalaria drugs are notable examples. There was no question that university scientists, and laboratories at universities like Berkeley, Chicago, and MIT, were critical to the war effort.

Near the end of the war, President Roosevelt—recognizing science’s remarkable achievements—turned to his science advisor, Vannevar Bush, for advice on how to mobilize science in the post-war period. Vannevar Bush (no relation to President 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."³ As the title suggests, Bush viewed science as a vast frontier of opportunities to serve the national interest. His report set the stage for the modern era of science and technology in the United States.

What were Vannevar Bush’s proposals? First, he asked "Who should fund the R&D effort of the United States?" For simplicity, I will use the terms “basic research”, “applied research”, and “development” to span the R&D continuum. Basic research is not focused on applications; the scientists involved tend to be interested in understanding some aspect of nature without necessarily trying to anticipate specific 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. If the applied research is successful, the work moves into the development stage involving the creation of new products and industries.

Vannevar Bush argued that applied research and development should be funded by the private sector, by industry. But he also argued that the private sector did not have the necessary incentives to invest in basic research. The economics of U.S. markets ensure that industry will invest in applied research and development, but those same market mechanisms will not produce an adequate investment in basic research. His view,

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 as to the company making the investment. There was no question about the long-term societal returns from basic research, but there was not necessarily an economic return to the specific company making the investment. Thus, he concluded that the federal government had principal responsibility for funding the nation's basic research effort.

The second question he asked was "Who should perform basic research, applied research and development?" Applied research and development, he said, is a private sector responsibility and should be performed—as well as funded—by the private sector. What about basic research? In most countries, publicly funded research has been carried out at institutes owned, managed and staffed by the central government; the United States has pursued a different path. Based on the experiences of World War II, Vannevar Bush proposed that American universities should be the principal performers of basic research with the federal government providing the necessary funds.

There was yet another part to Vannevar Bush's analysis. He argued that university research should be funded via a peer review process.⁴ Individual scientists would make proposals for research they thought was valuable. A group of peers (leading scientists from around the country) would evaluate the proposals and decide which to fund and which not to fund. This evaluation—the peer review—is the critical factor in ensuring that the best science is funded. Funding for basic research is one of the few areas of the federal budget that is not greatly affected by pork-barrel legislation.

Those were Vannevar Bush's proposals: 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 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 the principal drivers of basic research, and both R & D itself and the U.S. economy have prospered. The United States is unique among nations in the role it assigns to universities for the conduct of basic research.

From its beginnings, UCSD was focused on becoming a first-rank research university. The founding faculty stressed the importance of recruiting outstanding faculty and the initial group included several Nobel laureates and many members of the National Academy of Sciences. Recruiting stellar faculty had a “snowball effect”. Other distinguished academics were in turn attracted to UCSD by the quality of the faculty already in place. And as the university grew in size, the faculty soon was regarded by academics around the world as one of the best.

Several years ago, the National Research Council (a branch of the National Academy of Sciences) conducted a reputational survey of the quality of faculty in doctoral programs throughout the United States.⁵ The details of the survey are complicated, but the end result provides a ranking of universities by the quality of their faculty. The top four public universities, in rank order, were UC Berkeley, UCSD, UCLA, and the University of Michigan. Combining both public and private universities, the top dozen, in rank order, were MIT, UC Berkeley, Harvard, CalTech, Princeton, Stanford, Chicago, Yale, Cornell, UCSD, Columbia and UCLA. Over time, public

universities have lost ground to privates, as indicated by the fact that only three publics—all University of California schools—were in the top dozen. Let me quote briefly from an article in *Change* magazine⁶ summarizing part of the study dealing with UCSD:

“UC San Diego rated extraordinarily well, particularly for an institution that became a UC campus as recently as 1964. It was rated 10th in mean score for faculty scholarly quality—higher than older and larger UCLA, higher than any public university campus in the United States except Berkeley, and higher than such highly regarded private universities as Columbia, the University of Pennsylvania, and Northwestern. Two of its programs—in neurosciences and oceanography—rated first in the United States. Three more programs at UC-San Diego rated from second to fifth, and nine more from sixth to 10th, for a total of 14 of its 29 doctoral programs that were rated in their discipline’s top 10.”

As I mentioned earlier, peer review is a key factor in federal funding for basic research. Given the quality of the faculty, it should come as no surprise that funding for research at UCSD has continued to grow at a remarkable rate. In any given year, UCSD is fifth, sixth, or seventh among all universities in terms of federal research funding. The annual expenditure for research at UCSD is currently almost \$600 million, which is about twice the amount of support UCSD receives from the state of California for its educational programs. No other university in the nation has this kind of balance between federal research funds and state educational funds.

I became chancellor of UCSD in 1980. The foundation for a world class faculty was already in place, and I was committed to building on that base by continuing to recruit outstanding scholars and researchers. But I also wanted UCSD to play a very aggressive role in the development of high-tech industry in the San Diego region. The model that I had in mind was rooted in my experiences as a professor at Stanford University from 1956 to 1975 and as a director of the National Science Foundation in the late 1970s.

Given Stanford's worldwide eminence today, it may be hard to believe that it was not a top-rank university until some years after World War II. In the late 1940s Stanford made a very deliberate decision to place the highest priority on recruiting truly stellar faculty, and, in turn, greatly expand its research programs. But the university also decided to play a very active role in the development of industry in the Stanford region. At that time, the nation's electronics industry was principally located in the Northeast and the Chicago area, with virtually no companies in California. Stanford encouraged its students—such as Hewlett, Packard, and Varian—to remain in the area after graduation and start their own companies, rather than joining a company in the East. I don't have time to go into the many things Stanford did to encourage industry-university cooperation, but it clearly paid off in the development of what is now called Silicon Valley. Over the years there has been a remarkable synergy between Stanford University and entrepreneurs and companies in the Stanford region.⁷

One of my goals as chancellor was to ensure that UCSD played a role in the San Diego region comparable to Stanford's role in the creation of Silicon Valley. I wanted to encourage industry-university cooperation and promote spin-offs of high-tech companies from university-based research. A priority was to establish a School of Engineering which would broaden the base for industry-university programs. There was significant opposition from other engineering schools in the University of California System who feared having to share limited resources, and opposition from some UCSD faculty for the same reason. The initial step was to establish a Division of Engineering with its own dean and begin recruitment of engineering faculty. A few years later the division was renamed the School of Engineering.⁸ We also needed to rethink our technology transfer

programs to ensure that they covered the full range of research activities at UCSD and were timely and effective in working with the private sector on issues of intellectual property.

The university became very active in the “San Diego Economic Development Council” and worked closely with corporate executives trying to decide whether or not to locate their companies in San Diego; we emphasized the value of being near a world-class university and the access companies would have to our research programs and graduates. We also offered to establish continuing education programs that would be directly relevant to improving the skills of their employees. In close cooperation with industry, we established interdisciplinary research centers in such areas as magnetic recording, molecular genetics, wireless telecommunication, supercomputing and structural engineering.

An organization called CONNECT was created that has as its goal the transfer of technology from the research laboratory to the formation of new high-tech companies. Working with start-ups as early as the business planning stage, it helps entrepreneurs identify sources of venture capital, form strategic alliances, and gain managerial and legal expertise. CONNECT has been a catalyst for many new companies spun out from discoveries at UCSD and other research institutions in the region.

San Diego has emerged as one of the high-tech centers in the world, with special emphasis on biotechnology, computing, and telecommunications. Some of the UCSD faculty became pioneering entrepreneurs in their own right. Irwin Jacobs, a professor of electrical engineering, left UCSD to start a company called Linkabit which pioneered wireless digital telecommunication. Jacobs then went on to found Qualcomm which is

now a Fortune 500 company. Ivor Royston, a professor of medicine, founded San Diego's first biotechnology firm, Hybritech. After the sale of Hybritech and Linkabit to large established corporations, the founders of these firms, and many of the people they had hired, proceeded to create new companies. Spin-offs from these companies populate the San Diego region as well as branches of international giants like Eli Lilly, Merck, Pfizer, Johnson & Johnson, Novartis, Nokia, Ericsson, and Sony. San Diego has about 150 wireless firms and the highest concentration of wireless workers in the world. Biotechnology companies and the San Diego businesses that support them are responsible for 55,600 jobs and \$ 5.8 billion in income. Today San Diego ranks first in the nation for the number of wireless telecommunications companies and the number of biotech companies located in the area.

When we examine the phenomenal transformation of the San Diego region over the last 25 years, the picture is quite compelling. The research capacity of the entire San Diego region has expanded, many new companies have been created, managerial, legal and business competency has increased, and the pool of investment capital has grown to meet the needs of the region. These activities have not been subsidized by funds from the State of California. Competitively won research grants at UCSD come from private foundations and federal agencies; regional networks like CONNECT are funded by local companies and business service providers, and UCSD's continuing education programs are supported by employer reimbursements.

Universities are priceless sources for ideas that create jobs, give birth to new industries, and stimulate economic growth. We are living in one of the most productive eras of scientific discovery in history. From agriculture to medicine, from aerospace to

nanotechnology, science is experiencing a series of revolutions that are remaking our ideas of what is possible. We have only just begun to tap this knowledge explosion, with its many implications for the nation's economic future. Research universities are key to that future.

¹ The website for the Association of American Universities is <http://www.aau.edu/>.

² A 1995 report by President Clinton's Council of Economic Advisors chaired by Dr. Laura Tyson.

³ Bush, Vannevar. *Science—the Endless Frontier*. Washington, D.C.: U.S. Government Printing Office, 1945.

⁴ Bush used the term “merit” in his report as the basis for awarding grants. However, his perspective on peer review was developed in associated documents and in congressional testimony.

⁵ National Research Council, *Research-Doctorate Programs in the United States: Continuity and Change*, Marvin L. Goldberger, Brendan A. Maher, and Pamela Ebert Flattau, eds. (Washington, D.C.: National Academy Press, 1995).

⁶ See David S. Webster and Tad Skinner, “Rating PhD programs; What the NRC Report Says...and Doesn't Say,” *Change* (May/June 1996): 24-44.

⁷ A number of people played a leadership role in Stanford's transformation, but the key individual was Fred Terman, the son of a Stanford faculty member. After attending Stanford as an undergraduate he went east to MIT to earn a Ph.D. in electrical engineering; the MIT faculty member who directed his Ph.D. dissertation was Vannevar Bush. During World War II Terman led one of several groups of scientists and engineers at the Lincoln Laboratory of MIT involved in the development of microwave radar. After the war he returned to Stanford, first as dean of engineering and later as provost. For additional information see C. Stewart Gillmor, *Fred Terman at Stanford: Building a Discipline, a University, and Silicon Valley* (Stanford, California: Stanford University Press, 2004).

⁸ Now called the Jacobs School of Engineering in recognition of Joan and Irwin Jacobs' remarkable support for the university.