MAINTAINING AMERICA'S COMPETITIVE EDGE:
Revitalizing the Nation's Research Universities

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Introduction

Since World War II, the federal government has maintained a partnership with the nation's research universities in research and graduate education that has been central to the success of the nation's advanced education and innovation system and produced extraordinary benefits for America and the world. Vannevar Bush envisioned the partnership in his seminal 1945 paper, "Science, the Endless Frontier." Bush said the nation needed to invest its resources and its faith in curiosity-driven, competitively awarded basic research, and that basic research was best conducted in the free environment of the nation's universities, where research would be linked to education and training of graduate students.

The success of the partnership relies on each partner fulfilling its obligations: the federal government by providing funds for research after a competitive merit review process, the universities by building facilities, training students, and recruiting faculty. The benefits of the partnership have included advancements in health, enhanced national security, and technological innovations that have fueled economic growth, created entire new industries, and fundamentally changed the way we live. (For examples, see attached graphics, which also can be found at http://www.aau.edu/research/societal_benefits.aspx.) At the same time, the partnership has helped the nation to produce top scientists and engineers and future leaders and entrepreneurs.

Today, much of the world seeks to emulate the American model. Yet the government-university partnership is increasingly strained, and our research universities face serious challenges. That is why four members of Congress have asked the Academies, and the Academies have asked this committee, to recommend actions by the federal and state governments, universities, and others to ensure the continued strength of the nation's research universities.

The nation has turned to the National Academies before to analyze these issues. In 1983, the Academies produced "Strengthening the Government-University Partnership in Science," a study that outlined the problems that had developed in the partnership, and from which came what eventually was called the Government-University-Industry-Research Roundtable (GUIRR).

In 2005, the Academies produced *Rising Above the Gathering Storm*, a seminal report that prompted lawmakers to approve the America COMPETES Act, which was based on its recommendations and authorized substantial investments in university research and science, technology, engineering, and mathematics (STEM) education. This Committee's new report will be a bookend to *Rising Above the Gathering Storm*, potentially of equal importance, as it will be about revitalizing the nation's research universities, where this transformative research takes place.

With all of the challenges facing research universities and the government-university partnership, it is not only fair but wise to ask whether a partnership model established before the midpoint of the 20th century is the one most likely to help us succeed in the 21st.

The AAU universities believe that it is, but that strengthening the partnership requires renewed understanding, commitment, and action on all sides. This paper will seek to lay out the challenges we face and make recommendations for the Committee to consider as it takes up its job. It is our hope that the Committee will reaffirm the model and its underlying principles, and make recommendations that strengthen and renew them for decades to come.

Origins of the Government-University Partnership

Prior to the Second World War, federal support of American universities was limited largely to the creation of the land-grant college system by the Morrill Act of 1862 and the subsequent expansion of applied agricultural research (Hatch Act, 1887) and cooperative extension services (Smith-Lever Act, 1914). During the 1930's, most universities received little federal support, and no comprehensive policy existed for federal support of basic research at universities. The primary sources of support for such university research were large philanthropic foundations and corporations, such as the Rockefeller and Carnegie Foundations and DuPont and General Electric. In fact, universities preferred private contributions to government support, as they feared accepting government funds could threaten institutional autonomy and research independence.

As the Depression shrank the availability of private research funds, it effectively laid the foundation for a broader government-university partnership for the advancement of scientific and technological research. World War II further cemented that foundation, as the federal government called upon America's top scientists – many working at U.S. research universities – to assist the war effort.

In 1940, at the initiative of Vannevar Bush, a respected MIT engineer, science administrator, and unofficial presidential science advisor, President Franklin Roosevelt created the National Defense Research Committee, which in 1941 became the Office of Scientific Research and Development (OSRD). One of OSRD's primary responsibilities was to oversee The Manhattan Project.

The involvement of American scientists in war-related research was extraordinary. In the course of the war, OSRD directed the work of 30,000 people, including, by one estimate, two-thirds of America's physicists, and was responsible for the development of some 200 weapons, including sonar, radar, the proximity fuse, and the Norden bombsight. OSRD also led efforts that resulted in major medical advances, including the widespread use of penicillin, new and improved means to combat malaria, new blood substitutes, and the use of immune globulin to fight infections.

In 1944, to build upon the tremendous wartime success of OSRD, President Roosevelt asked Bush for a report on how the United States might best develop and distribute the benefits of scientific research in a postwar era. Bush's response, "Science, The Endless Frontier," was delivered to President Truman in 1945 and has formed the basis for America's policy on scientific research ever since.

Bush insisted that basic scientific research was essential for advances in medicine and the battle against disease, for sustaining the nation's national security in peacetime as in wartime, and for releasing "the full and productive energies of the American people" to create new jobs with "new vigorous enterprises." To achieve these ends, he argued, the nation must invest public resources in basic research and the development of scientific talent. Bush wrote:

> *Publicly and privately supported colleges and universities and the endowed research institutes must furnish both the new scientific knowledge and the trained research workers. These institutions are uniquely qualified by tradition and by their special characteristics to carry on basic research….It is chiefly in these institutions that scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity….*

In the decades after the Second World War, the federal government implemented the basic components of Bush's program. It created federal agencies and developed programs to support university research and graduate education that allocated funding competitively, based on the quality of the science. Indeed, an essential characteristic of the U.S. system for fostering basic research was, and continues to be, that graduate education and university research are conducted in the same place by the same people, thus enriching both activities. The education of graduate students is enriched by their direct engagement in research, working side-by-side with their faculty mentors, while the quality and productivity of research is enhanced by the creativity and energy of talented graduate students. This is a primary reason that federal funding of research has both led to world-changing discoveries and helped support the training of successive generations of scientists and scholars.

During this period, states began to invest substantial resources in their public universities. The GI Bill provided opportunities for more students to attend college, and the arrival of the baby boomers in the 1960s led to a major expansion of higher education in America. The growth of universities increased the number of faculty trained to conduct research, expanding the nation's capacity to capitalize on the growing federal investment in basic research.

The government-university partnership developed, therefore, with each partner investing in the nation's research enterprise: the federal government by providing funds for research, distributed by the various government agencies after a competitive merit review process, the universities by building the facilities, training students, and recruiting the best possible faculty. Each partner depended on the other to fulfill its obligations.

The federal government-university partnership has served the nation exceedingly well. The vision developed by Vannevar Bush 65 years ago laid the foundation for the basic research enterprise of the United States and helped make its research universities global leaders. The combination of strong, well-endowed private universities and large, comprehensive flagship public universities combining research and education helped make American higher education the envy of the world in an era in which the vast expansion of knowledge became the basis for economic growth and national security. The absence of central controls and the competitive environment that flourished among these universities and their research faculty stimulated a remarkable quest for excellence and scientific advancement.

Emerging Challenges to the Government-University Partnership in the Post-Sputnik Era

Responding to the launch of Sputnik in 1957, the government dramatically expanded investment in research programs. Between 1958 and 1964, federal funding of academic research increased an average of nearly 20 percent annually. However, increases slowed in the following years, dropping to an average of less than two percent per year in constant dollars between 1968 and 1983. Since 1983, federal funding of academic research has increased by an average of about three percent annually, though closer to two percent between 1990 and 2008.

By the 1980s, a number of stress points had developed in the government-university partnership. The slowing of government support for research left a number of needs unmet: equipment and instrumentation were not keeping pace with scientific opportunities, and graduate student support lagged. The recession of the early 1980s led to cutbacks in state support for public universities, and there was concern that the federal government was not adequately covering the costs institutions incurred in sponsored research. In addition, the collaboration between industry and universities was not as productive as it needed to be; nurturing this collaboration and stimulating innovation was the objective of the Bayh-Dole Act of 1980, which granted universities the right to license patents produced by government-funded research.

In response to these concerns, the National Academies produced a study in 1983 entitled, "Strengthening the Government-University Partnership in Science." From this study came a forum that eventually became the Government-University-Industry-Research Roundtable. GUIRR has worked to bring its three components into closer alignment. It has sponsored numerous projects that address government policies that affect industries and universities, most notably the Federal Demonstration Partnership and the University-Industry Demonstration Partnership.

Current Status of the Government-University Partnership

Much has changed since the nation implemented Bush's vision. In many respects, the relationship remains strong. Nearly 70 agencies and offices fund $31.2 billion in research projects and graduate student support at the nation's colleges and universities annually, and the output of ideas, discoveries, and people remains extraordinary. Yet there is reason to worry about important aspects of the partnership and to wonder whether the nation's research universities can continue to sustain their position of world leadership. Among the challenges are the following:

- **Universities' declining revenue base.** Even before the current recession, state support for flagship universities, measured on a per-student basis, had been declining for two decades.

According to Forging a Foundation for the Future, a recent report by the Association of Public and Land-grant Universities, there was a 9.1-percent decline in real appropriations per full-time enrolled student between 1988 and 2008. Competing claims on revenue by primary and secondary education, welfare, Medicaid, and law enforcement and corrections have shrunk available discretionary funds and made higher education a lower priority. The current recession has resulted in states reducing support for their universities even further. Flagship public universities have had to resort to faculty and staff layoffs or furloughs, the termination of programs, and steep increases in tuition and fees for students. In some states, notably California, whose public research universities are among the best in the world, the reductions have been massive, resulting in tuition increases that limit access to students lacking the means to pay the increased costs. It is doubtful that state support will ever recover to the levels appropriated even a decade ago.

The sharp drop in the value of endowments also has eroded university operating budgets, particularly those of private universities. Endowments lost an average of nearly 25 percent of their market values between 2008 and 2009, according to the NACUBO-Commonfund Study of Endowments. With anticipated rates of return, annual payouts, and the likely effects of inflation, it may take two decades or more for many endowments to recover their losses.

Fundraising has suffered as well, with 60 percent of colleges and universities reporting a decline in gifts in 2009. The median decrease was more than 45 percent.

- **Increasing international competition.** Having witnessed the vital role that American universities have played in our nation’s economic growth through the innovative science, technology, and students they have produced, other nations are investing in research universities to advance their societies, as well. China increased its R&D spending as a percentage of GDP by more than 250 percent between 1995 and 2007; it is building new research universities at an astounding rate, and it is recruiting top-notch U.S. talent to run them and to conduct research. American faculty members visiting China’s top institutions have marveled at the quality of their facilities and state-of-the-art equipment. Russia, Germany, Switzerland, Korea, Japan, and India are making similar strategic investments in building and renewing their research universities.

  American research leadership depends on its universities. The major industrial laboratories conducting basic research, like Bell Labs, have largely disappeared. If American universities are also allowed to deteriorate, and are seen as deteriorating, the nation will lose its major comparative advantage. In a global market, talented international students will elect to study elsewhere. For example, while the number of international students pursuing degrees in the United States increased between 2000 and 2009, our share of the overall international student population declined by more than five percent. Other nations - including Japan, Canada, the United Kingdom, and China - increased their share during this same time period. The number of international students studying in China grew from around 77,000 in 2003 to nearly 240,000 in 2009. Not only students but faculty, seeing greater opportunity abroad, will begin to follow suit and pursue career opportunities elsewhere. China’s “Thousand Talents Program,” for example, aims to attract some 2,000 talented overseas Chinese to return to China over the next five to ten years.

We would be wise to remember Vannevar Bush's warning: *"A nation which depends upon others for its basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill."*

- **Universities bear an increasing portion of the cost of research and compliance with federal regulations.** Both the federal government and universities benefit from their partnership, and take risks by making investments with uncertain results. In a fundamental way, universities take the larger risk, incurring substantial costs associated with conducting research – constructing buildings, creating infrastructure, purchasing instruments, hiring faculty – with many of those costs recouped only when research grants are awarded to their faculty. That risk becomes even greater when those costs, particularly for facilities and administration, are not fairly reimbursed.

  It has been a principle of the partnership between the federal government and universities that the government reimburses an agreed-upon portion of the costs that universities incur for facilities and administration, including the cost of complying with federal regulations. This principle dates to the early contracts and awards made to universities by OSRD during World War II.

  However, AAU has submitted to the Committee a study of indirect cost reimbursement which demonstrates that universities are bearing a greater portion of the overall cost of conducting research than in the past. (See "Strengthening the Government-University Partnership: A Discussion Paper on University Indirect Cost Reimbursements.") Analyses of cost-sharing practices show that the 26-percent reimbursement cap on the administrative portion of Facilities and Administration (F&A) costs prevents universities from being reimbursed appropriately for the costs of research. Moreover, federal agencies often do not reimburse universities for certain research projects and programs at the full negotiated F&A cost rates. In some instances, such as USDA-funded research, restrictions on reimbursements of F&A costs have been imposed by statute.

  "Taken together," AAU's analysis states, "we estimate that the total in unreimbursed indirect costs being paid for with institutional funds by universities to conduct research on behalf of the federal government ranges between $2.1 billion and $3.8 billion – $1.4 billion to $3.1 below the cap plus $0.7 billion above the cap. The expenditures vary from institution to institution, but clearly amount to annual costs on the order of tens of millions of dollars at most major research universities." Concerns about current Office of Management and Budget (OMB) and agency policies relating to F&A reimbursements have caused both the National Science Board and the Government Accountability Office (GAO) recently to urge the government to review its F&A policies.

  Since 1991, when OMB modified OMB Circular A-21 to limit administrative cost reimbursement, substantial new regulatory and compliance requirements have driven up the costs of conducting research. While most of these compliance requirements are intended to ensure that research is conducted in a responsible and safe manner, they have added substantially to the cost of conducting research at universities. Much of that added cost has not been reimbursed because of the reimbursement caps.

  In addition, federal compliance and audit officials too often focus on process and documentation in their reviews of compliance systems, with no regard to research outcomes.

So effort reporting, cost transfers, cost sharing, graduate student compensation, and other areas of compliance become targets for forcing universities to repay grant funds or reach agreement on settlements, with no consideration of universities' contribution to advancing knowledge, generating new ideas, inventions, and therapies, and training the next generation of scientists, as well as universities' financial support of research costs.

It should also be noted that when foundations and the private sector fund research at universities, they increasingly are requesting that universities waive or greatly reduce payments for indirect costs. This, too, adds to the costs borne by universities.

Perhaps even more troubling than the institutional costs to universities is the increased administrative burden on faculty. Comparing surveys of faculty time spent on administrative matters in 2007 with a similar study done two decades earlier, the Federal Demonstration Partnership found that current faculty members reported spending 42 percent of their time on administrative and compliance matters compared with 18 percent in the earlier survey. This constitutes a significant diversion of faculty time from productive scientific research and mentoring students.

- **Challenges to the economic value of basic research.** Vannevar Bush stressed the importance of basic research and the responsibility of the federal government for supporting it. He distinguished it from applied research:

> *"Basic research is performed without thought of practical ends. It results in general knowledge and an understanding of nature and its laws. This general knowledge provides the means of answering a large number of important practical problems, though it may not give a complete specific answer to any one of them. The function of applied research is to provide such complete answers. The scientist doing basic research may not be at all interested in the practical applications of his work, yet the further progress of industrial development would eventually stagnate if basic scientific research were long neglected.*
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> *"One of the peculiarities of basic research is the variety of paths which lead to productive advance. Many of the most important discoveries have come as a result of experiments undertaken with very different purposes in mind. Statistically it is certain that important and highly useful discoveries will result from some fraction of the undertakings in basic science; but the results of any one particular investigation cannot be predicted with accuracy."*

It is important to recall this admonition in an era in which there is great eagerness to "translate" research into commercial applications and there are calls for university research to produce more immediate innovation and new commercial ventures. The government-university partnership has already led to countless new industries that have fueled the growth of the American economy. Since the passage of the Bayh-Dole Act in 1980, patents derived from university research have grown at an impressive rate. In 1985, the U.S. Patent and Trademark Office awarded around 500 patents for the top 200 U.S. research institutions. In roughly comparable figures for 2008, 3,280 U.S. patents were issued to U.S. universities, while 595 new companies were formed and 648 new products were introduced based upon university inventions.

While universities need to make every effort to ease the transition of ideas into inventions, calls to shift federal investment at universities from basic to applied or targeted research that will more quickly lead to commercial applications threaten the well springs of creativity and undermine confidence in the ultimate importance of basic research itself.

More broadly, research universities, particularly public institutions, are increasingly seen in many states and regions not only as an essential element of their innovation initiatives but as the primary driver in that process. While universities do play a critical role, it is important that demands not be placed on them that take them from their fundamental roles of education, research, and service.

- **Changing demographics, changed public perceptions about higher education.** During the last several decades, social changes have brought new challenges and demands upon universities, enlarging their obligations during a period of diminished resources. America's population has changed with the growth of an immigrant and minority population that historically has been, and continues to be, underrepresented in our universities. Universities have made concerted efforts to expand access for first-generation college students and will continue to advance those efforts. To accomplish this, universities increasingly have become engaged in improving the quality of K-12 education, which is failing in many communities.

  At the same time, public attitudes toward higher education have shifted. Throughout the expansion of higher education, from the first GI Bill through the 1960s and 1970s, public investment in higher education was understood to be investment in the public good, benefiting not only those being educated, but society as a whole. During the last three decades, higher education has come to be viewed increasingly as a private good, benefiting primarily those receiving it, who should therefore be expected to bear a higher percentage of the cost of providing it. Thus, the loss of state support for universities is due only partly to competing demands for scarce resources; it is also a reflection of a changing attitude toward public goods in general.

- **Rising costs.** With the decline of state support of public higher education, students and their families are expected to underwrite a larger portion of the cost of their education. The loss of state funds is exacerbated by rising costs due to many other factors, including increasing costs of labor, health care, technology, compliance with government requirements, and student services, as well as the cost of financial aid to keep up with those other costs. These, of course, are issues for private as well as public institutions.

  As tuitions have risen, so have levels of student debt, even as institutions have increased financial aid dramatically in an effort to keep up with costs. Indeed, the United States ranks first in family household contributions to higher education, according to the Organization for Economic Co-operation and Development.

  It does not help that the "sticker price" tuition, which is actually paid by only a relatively small number of students, undermines our collective ability to communicate to first-generation students that any qualified student can attend college. While universities strive to control costs and to provide aid to students in need, rising tuitions remain a barrier – even if it is more often perceived than real – to many families.

This has a particular impact on America's research universities, which typically have highly selective admissions and relatively high tuitions. Those students who do leave their undergraduate studies with more debt are more inclined to pursue remunerative professional careers than to enroll in graduate programs to pursue careers in research. Moreover, state legislatures, concerned about increasing tuition for the undergraduate education of their constituents, are unsympathetic to the support of graduate students, who often are not constituents and leave the state upon completing their degrees.

- **The challenge of maintaining disciplinary balance within universities.** Reflecting fundamental American pragmatism, American universities have historically been structured to serve society in very practical ways. The creation of the land-grant universities in the nineteenth century made possible the expanded productivity of American agriculture, mining, and manufacturing. Private universities as well adopted a mission of public service with the development of professional schools. Yet even with its practical emphasis on creating land-grant universities focused on "agriculture and mechanic arts," the Morrill Act called upon these institutions not to exclude "scientific and classical studies." Universities were considered an essential component of a democratic society, educating the citizenry for participatory democracy and developing enlightened leaders. While the preservation of America's leadership in scientific research is essential, it should not be accomplished at the expense of balance between the scientific and humanistic disciplines. All too often, the shortage of resources in universities to sustain expensive scientific and technological disciplines results in diminished resources for the humanities and social sciences. Many university presidents have expressed this concern about maintaining support for the humanities, social sciences, and the arts in discussions about the challenges confronting their institutions. Again, Vannevar Bush's admonition is pertinent: *"It would be folly to set up a program under which research in the natural sciences was expanded at the cost of the social sciences, humanities, and other studies so essential to national well-being."*

  Although a study of the of the future of America's research universities undertaken under the auspices of the National Academy of Sciences is not specifically charged to concern itself with the impact of federal, state, and institutional policies on the non-scientific endeavors of universities, the Committee should be aware of the importance of disciplinary balance within universities and the importance of sustaining the humanities and social sciences within universities.

Looking Forward: the Future of the Government-University Partnership

The National Academies has been asked to consider what each of the partners – the federal government, the states, and the research universities – must do to enhance the partnership and secure the future of the nation's research universities. To be most effective, the Committee should look upon this task as the development of a national strategy for ensuring the long-term quality and strength of the nation's research universities.

In doing so, perhaps the first thing the Committee should do is reaffirm the principles of the government-university partnership. The American research enterprise has been guided since the Second World War by the principle that the role of the federal government was to invest in basic research. It has placed its confidence in the efficacy of curiosity-driven research, evaluated by a rigorous merit review process. It has sought to insulate research from political considerations and sustain the freedom of talented scientists to pursue fundamental scientific discoveries. These principles should be reaffirmed.

As the Committee considers the other elements of a national strategy, AAU makes the following suggestions for the federal and state governments, and universities themselves:

<u>The Federal Government</u>

- **Fund research sufficiently and predictably.** Unlike some nations that have embarked on national strategies to develop their research universities, the United States does not have a centralized ministry for research or a central agency that directs the allocation of resources toward specific institutions for specific purposes. This has been to our advantage. Although the federal government early on supported the creation of universities, and it has invested large amounts in financial aid to students, we have relied on a decentralized system of higher education and research. American universities enjoy a wide degree of independence and self-governance.

  This decentralized, competitive system for conducting research has served the nation well, and it is critical that it be sustained. Nevertheless, as recent history has shown, the system is subject to the vicissitudes of state funding, endowment returns, and federal appropriations for research.

  Consider the variability of federal appropriations over recent decades. In constant dollars, year-to-year changes in academic research funding between 1983 and 2008 varied between an increase of 13 percent and a decrease of more than five percent. This variance is reflected in individual agency budgets. For example, the National Institutes of Health (NIH) has seen annual fluctuations in its budget of anywhere from a decline of 10 percent to an increase of 17 percent. The National Science Foundation (NSF) has seen year-to-year declines of up to five percent, and increases of nearly 10 percent. For both agencies, around 55 percent of their total budgetary increase between 1982 and 2008 can be accounted for by the five-year period between 1999 and 2003.

  Boom and bust cycles for research have plagued the partnership. The busts critically reduce the percentage of applications that can be funded and undercut the investments universities make in facilities and faculty. The substantial research expenditures under the American Recovery and Reinvestment Act were a welcome investment that will reap handsome dividends for the nation in the long run. Those expenditures, however, are temporary, and while universities may be better prepared than they were following the five-year doubling of NIH, there still is reason for concern about the impact when the funds expire.

  The federal government should end damaging fluctuations in research appropriations and instead provide steady, sustainable, predictable increases over the long term. This would enable universities to plan their own investments in research, and it would make federal research expenditures more effective and efficient. The COMPETES Act was an effort to accomplish this with respect to the agencies funding the physical sciences. The COMPETES Act should be reauthorized and then funded, and a similar effort to lay out a predictable funding path should be made for biomedical research.

- **Recognize the federal role in graduate education.** The intricate interconnections between graduate education and research in the nation's research universities are a core strength of the American innovation system and critical to maintaining our competitive edge in a global economy. U.S. graduate programs have been recognized as the best in the world, and have thereby been able to attract the most talented students and faculty worldwide.

  However, we have not been as successful recently in attracting and retaining the best and brightest students within the U.S., particularly in STEM-related fields. For example, according to National Science Board 2008 data, fewer than 300,000 college students selected STEM majors, and only about 167,000 are expected to earn STEM degrees by 2011. Past studies have found that of college freshman planning to pursue STEM majors, approximately 40 percent will have changed their majors to non-STEM fields by their senior year. These dropout rates in STEM fields are even worse for students from underrepresented minority groups.

  In addition, according to a recent report by the Commission on the Future of Graduate Education in the United States, 82 percent of doctoral degrees awarded in the U.S. in 1977 were granted to U.S. citizens, but this figure had fallen to 57 percent by 2007. The proportion of engineering (29 percent, down from 56 percent) and physical sciences (43 percent, down from 76 percent) doctoral degrees awarded to citizens have shown even sharper declines.

  Moreover, our continued capacity to attract top international talent will be challenged by the growing strength of universities in other countries. UNESCO data show that an increasing number of students from Asian countries, in particular, are attending universities within their own region. In East Asia and the Pacific, 42 percent of students remained in their region in 2007, compared to 36 percent in 1999.

  As a function of an increasingly knowledge-based economy, the U.S. Bureau of Labor Statistics projects that jobs that typically require a master's or doctoral degree are likely to increase 17-18 percent between 2008 and 2018, with a projected estimate of 2.5 million additional jobs. This is in part because most doctoral degree holders work in occupations in service industries—generally in professional, scientific, and technical services or in government—all of which are projected to grow over the next ten years.

  Given this backdrop, it will be difficult, yet even more important, to maintain high-quality graduate education programs, with a healthy balance of domestic and foreign students. Several recent studies, such as "Rising Above the Gathering Storm," recognize graduate education as a national need, suggesting that the federal government should establish long-term goals and provide more robust support for graduate education as a means of invigorating our own graduate student talent pool.

  This will require strengthening the link between research and graduate education. Most federal agencies supplying external support through fellowships and traineeships do not pay the full cost of education, with the expectation that institutions or students will fund the gap. At the same time, both public and private research universities are faced with serious financial challenges. Recognizing that graduate education is considerably more expensive than undergraduate education, the federal government should provide greater institutional support for graduate education, either through direct subsidies or by allowing indirect costs to be applied to graduate student support funded through research grants. In addition, we should improve existing research fellowships and traineeships by strengthening the research components and reinforcing the connection between research and graduate education in faculty research grants.

- **Support for young faculty.** The nation's future research depends on its ability to attract the best minds to careers in research. Young career award programs by federal agencies have helped assure that outstanding young faculty members have the freedom to launch their research careers. Yet, the average age of a first-time major grant recipient at NIH has risen to 42, and as a result of the recent financial crisis, senior faculty are postponing retirement and universities have reduced the hiring of young faculty. It is important that the nation develop additional programs to attract and support young researchers.

- **Increased support for facilities and equipment.** During the 1960s, when the largest expansion of American research universities occurred, NSF and NIH created programs for the construction of facilities and for the acquisition of large, expensive equipment. At their highest level, they awarded grants for facilities totaling slightly less than $1 billion in 2009 dollars. To provide researchers with state-of-the-art laboratories and equipment, universities must invest in costly facilities. While some equipment may be acquired through federal grants, there remains an unmet need for funding. Making certain that American research faculty have facilities and equipment as up-to-date as competitors around the world should be a goal of all government funding agencies.

  Some facilities and large equipment costs are ultimately reimbursed through F&A payments; however, as previously noted, there are often artificial limitations on how much can actually be reimbursed. For public universities, the facilities problem has been exacerbated by the decline in state support for such facilities. A program contingent on matching funds from states, industry, and/or donors for the construction or renovation of facilities would ease the cost burden of universities. The Committee might look at the Canadian Innovation Foundation as one model for supporting research infrastructure at U.S. universities.

- **Reexamine and reform federal F&A reimbursement policies and practices.** As noted earlier, AAU has submitted to the Committee a paper on F&A reimbursement policies and practices. As asserted in that paper, major reforms are needed. In general, OMB, working closely with OSTP and federal research agencies, should examine current F&A reimbursement policies and practices to ensure that they appropriately reimburse universities for the costs they incur to conduct research on behalf of the federal government.

  More specifically, the following actions should be taken: 1) OMB should mandate that agencies adhere to the rules set forth in Circular A-21 and specifically prohibit agencies from paying universities less than their negotiated indirect cost rates; 2) Congress should eliminate the statutory restrictions on indirect costs for research funded by USDA and the Department of Defense; 3) OMB should lift the 26-percent cap on administrative costs to a more appropriate level; 4) in accordance with a recent GAO report, OMB should identify ways to ensure that the rate-setting process for reimbursement is applied consistently at all schools, regardless of whether their rates are set by the Department of Defense or the Department of Health and Human Services; and 5) OMB should reexamine other inequities in current reimbursement policies across institutions, such as the utility cost adjustment.

In addition to these actions by the federal government, private foundations and industry should not ask universities to waive or reduce indirect cost payments. Finally, and of equal importance, universities have a responsibility to find ways to reduce costs and should review their administrative and compliance functions periodically to ensure they are performed as efficiently and effectively as possible.

- **Call for a review of compliance and regulatory requirements.** Universities must be accountable for the federal funds they receive; compliance with federal regulations is an essential condition for the receipt of public funds. The imposition of new regulations and a continuing stream of new reporting requirements, however, do impose new costs on universities which should be included in the calculation of indirect costs. Some regulations should be reviewed with the goal of finding less costly and equally effective ways of monitoring compliance.

  Effort reporting, for example, is extraordinarily complex, and the auditing of compliance varies widely. The reporting is based on premises that do not easily apply to research work and it fails to evaluate the outcome of the effort, which should be the primary consideration of the federal government. The Federal Demonstration Project is examining an alternative to current effort reporting requirements that would still ensure research accountability. Other reasonable alternatives also should be explored.

  Additionally, steps should be taken to harmonize regulatory requirements across federal agencies. Individual research agencies often create rules and regulations to meet statutory requirements, but these requirements are very different from one agency to the next. This subject-by-subject, agency-by-agency approach is very inefficient. It reduces research productivity and the return on federal research investments. A more streamlined, interagency approach would lead to more uniform and consistent, and therefore more efficient, rules across the federal research agencies.

  Finally, it is time to reconsider the burdensome reporting requirements imposed on faculty. While transparency and accountability are critical to ensuring that research dollars are well spent, there comes a point where such reporting requirements impose real costs upon researchers and their ability to conduct research. New methods of automated reporting need to be developed, and we need to explore and implement additional ways of supporting growing administrative requirements without further burdening faculty researchers.

- **Immigration Reform.** The Committee should encourage Administration and Congressional efforts to reform the nation's immigration laws and policies. A high priority should be to streamline the permanent residency process for individuals graduating from a U.S. university with a STEM doctoral or master's degree. Another priority is to reform the temporary work authorization visa process (H-1B visas). Our national interest is best served when the world's top students, scientists, researchers, and engineers can live and work in the United States. Their contributions not only keep the U.S. on the cutting edge of innovation and technology but also help to stimulate the nation's entrepreneurial spirit and create more jobs for Americans.

The States

In the case of public research universities, the government-university partnership is, in reality, a federal-university-state partnership, for the universities cannot easily uphold their obligations to the federal research agenda without adequate support from their states. While the federal government cannot compel the states to increase their support for flagship universities, it can create incentives for them to do so. A national strategy to sustain research universities might involve programs that rely on federal-state matches that require maintenance of effort by the states.

The states, however, even in the absence of such a federal program, need to reconsider their destructive actions toward public higher education, particularly their research universities. They need to consider the extraordinary roles these institutions play in their states and consider the consequences of their diminishment. The states are facing great fiscal challenges. Cutting back on these critical investments may be making such challenges even more difficult in the long term.

States also should reduce the many regulatory controls they continue to exercise over universities. Many flagship universities now receive less than 20 percent of their operating budgets from the states; some receive less than 10 percent. However, state governments still impose numerous rules and constraints on those institutions as though they still provided the majority of support. Some states, like Virginia, have negotiated new compacts with their flagship campuses that eliminate costly and burdensome regulations. Other states, like Oregon, are discussing ways in which flagship universities can negotiate a new model for state support, and begin operating more like public corporations than state agencies. State matches for certain private endowment donations could also provide incentives for private donors or foundations to increase their support for research universities.

Because state resources are not likely to recover in the near future, states should begin to seek ways of leveraging their support to enhance the capacity of their major flagship campuses.

The Universities

- **Address costs.** The public commonly assumes that universities make little effort to contain costs and that they simply increase tuition in order to cover the increased expenditures they wish to make. Those outside of the academy, unfamiliar with how universities actually operate, often say that they simply should adopt more business-like practices. In fact, universities work very hard to contain costs. Several have engaged professional consulting firms to help them benchmark their expenditures and organizational practices against the standards of similarly sized organizations and businesses, with the goal of identifying and adopting best practices. Many universities have adopted Responsibility Centered Management, under which schools and colleges within universities manage the resources they generate while being taxed for the central services and space the university provides them. This has driven cost-consciousness to lower levels of management in the universities and resulted in significant efforts to economize.

  The loss of revenues for both public and private universities following the recession and financial crisis has forced wrenching cuts on most campuses. Universities have carried out layoffs, imposed furloughs, frozen or reduced pay, postponed or eliminated long-planned projects, reduced programs and course offerings, and reorganized for greater efficiency,

Many factors drive the costs of universities because the modern American university is much more than a collection of classrooms, laboratories, students and faculty. It is a complex organization with multiple obligations. Nevertheless, it will be important for universities to find the means of "bending the cost curve" in new ways. The following examples should be explored:

- **Explore new modes of instruction.** While undoubtedly savings can be achieved and costs reduced by reorganizing and consolidating administrative functions, reducing costs of education will not merely be a matter of controlling tuition increases. It will also require the exploration and development of new modes of instruction, perhaps principally through forms of on-line instruction that permit students to move through parts of their curriculum at their own pace, acquiring credit less by the number of hours spent in a classroom than by demonstrating achievement, competency, and the ability to move to the next level of the curriculum. On-line instruction is not necessarily less expensive to deliver, but the savings may be achieved by shortening the time students require to obtain their degrees. Experiments are underway to test the efficacy of on-line instruction at traditional universities.

- **Regional collaboration among research universities.** The cost of modern research facilities and equipment and the concentration of talent to undertake research in a number of fields may be more than any one university can afford. Universities should consider developing regional collaborations with shared facilities. They should enable students to move more freely among institutions to secure the specialized training they need without the burden of non-resident tuition. This will require a new understanding of public universities by the various states and the reduction of constraints on them.

- **Increase the number and diversity, of students majoring in STEM disciplines.** A significant number of students who enter college intending to major in science, engineering and mathematics do not end up majoring in these disciplines. Universities need to examine the reasons for this and develop strategies for retaining students in these disciplines, including improving the quality of STEM education, particularly at the undergraduate level.

  Much is known about how this can be accomplished, but this knowledge needs to be applied by faculty in the classroom. To encourage faculty to do so, universities must create incentives for their departments to place more emphasis on effective teaching of STEM disciplines. In addition, universities should develop or expand undergraduate research opportunities for their students, as well as expand the use of cohort programs which have demonstrated effectiveness in the recruitment and retention of women and minorities in STEM-related disciplines. They should also continue to establish and build on professional science masters programs and develop other programs that help undergraduate students to understand and pursue alternative STEM careers. Programs that encourage STEM students to pursue teaching careers at the elementary and secondary level, such as the U Teach program started at the University of Texas at Austin in 1997, should also be expanded.

- **Build on existing successful and sustainable interventions to improve time to degree and completion rates.** Students in graduate programs in U.S. universities take too long to earn their degrees, and completion rates need to be higher. The Council of Graduate Schools recently found that, in mathematics and the physical sciences, only 23 percent of students complete their doctorates within five years, and only 55 percent within ten years. Universities should review and analyze their completion and attrition patterns at the doctoral level (including disciplinary, gender, and ethnic disparities) and create or continue interventions to reduce time to degree and increase completion.

Conclusion

No doubt other ideas for sustaining the strength of America's research universities will emerge in the course of the study by the National Academies. Whatever the means, the goal must be clear: to maintain our leadership in the world, to attract and educate the most talented young people, and to provide a secure and prosperous future for all Americans, we must make certain that our research universities have the resources, the regulatory framework, and the freedom necessary to fulfill their missions. The health of these institutions is essential for the nation's future.

# # # # #

The Laser – "A Solution Looking For a Problem"

Critics dubbed the laser "a solution looking for a problem." In fact, it took years for many potential uses of the laser to be recognized, and new laser applications are still being discovered today.

The basic research behind the laser was funded by the Department of Defense. Later applications were discovered as a result of other federally sponsored research and technological advances. Today, the laser has many everyday applications and is vital to the U.S. military, to health care, to consumer and business electronics, and to many other industries.

The laser is just one example of how basic research, which may begin with no specific technology or product in mind, can lead to important discoveries, life-changing inventions, and economic growth.

Invest in Basic Research: You Never Know Where it Might Lead…

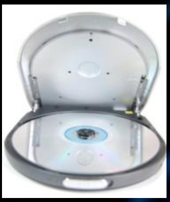
Examples of Laser Applications

1964 Laser Guided Weapons

1969 Laser Printer

1970 Fiber Optic Communications

1974 Bar Code Scanner



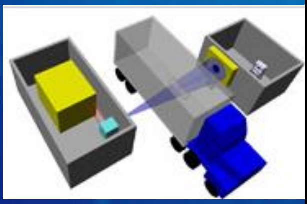
1982 CD Player

1987 Laser Vision Correction Surgery

1989 Hologram Authentication

1995 DVD Player

20?? (in development) Detection of Nuclear Materials



DOD Research: Empowering and Supporting Our Troops in Combat

a **HEMCON BANDAGE: The** HemCon bandage stops hemorrhaging within minutes. Research and development funded by the Army and performed by the U.S. Army Medical Research and Material Command.

b **INTERCEPTOR BODY ARMOR:** Flexible, lightweight, highly ballistic-resistant body armor system that protects soldiers in combat. Materials and engineering design research sponsored by the Marine Corps, Army, and DARPA.

c **JOINT PRECISION AIR DROP SYSTEM:** Improved air delivery drops food and equipment closer to soldiers, increases survivability of aircraft personnel and supplies, makes humanitarian relief more efficient. Joint Army/Air Force research.

d **LASER DESIGNATOR:** Laser sights increase precision of weapons in the field. Laser research started at Bell Labs in the 1950s and later sponsored by the Army and Air Force.

LUMINESCENT POLYMERS FOR EXPLOSIVE SENSING: DOD-sponsored research has identified nanotechnologies that detect hidden improvised explosive devices (IEDs).

e **MEAL, READY-TO-EAT:** Advanced technologies protect food rations from deteriorating in extreme environments, enhance soldiers' physical endurance, help detect food contaminates. Army-sponsored research at Natick Soldier Research, Development and Engineering Center.

f **NIGHT VISION GOGGLES:** Photoelectric effect allows soldiers to see images in very low light. Current night vision technology is result of DOD research.

g **SOLDIER PERSONAL DIGITAL ASSISTANT:** Soldiers receive situational awareness and other information using:

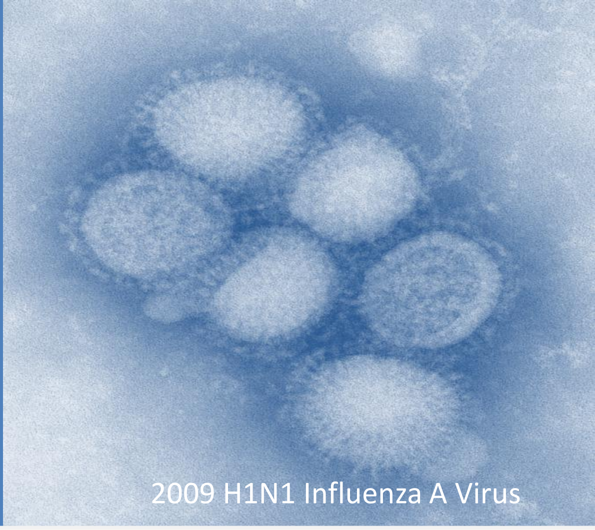
- **GPS:** Basic research funded by Air Force, Navy, and AEC (now DOE) led to global positioning system, which gives a soldier's specific location anywhere in the world.
- **WEARABLE SOLDIER RADIO TERMINAL:** Provides voice communications and links soldier's' personal digital assistant to FalconView software, which networks and maps soldiers on the battlefield. Research funded by several DOD offices.
- **LITHIUM PRIMARY BATTERIES:** Lighter, longer-lasting power source for soldiers built on basic research funded by DOE and applied research funded by Army and DARPA.

h **SOLDIER TRAINING:** Gaming technology and simulation of battlefield environments prepare soldiers for deployment and provide theater mission training. Underlying technologies developed from Army-funded basic research.

i **TRANSLATION DEVICES:** Highly accurate voice recognition technology allows soldiers to generate and interpret speech in other languages. Original technology resulted from DARPA-sponsored research and improved by other DOD agencies.

Vaccines Today: Faster Than Ever

Sustained NIH investment enables today's scientists to develop vaccine candidates and vaccines faster than ever.



2009 H1N1 Influenza A Virus

Polio

- The initial U.S. outbreak of polio occurred in Vermont in 1894.
- Poliovirus was originally identified in 1909, by Karl Landsteiner and Erwin Popper.
- The first human clinical trials began 45 years later, using a vaccine developed by Jonas Salk.

West Nile Virus

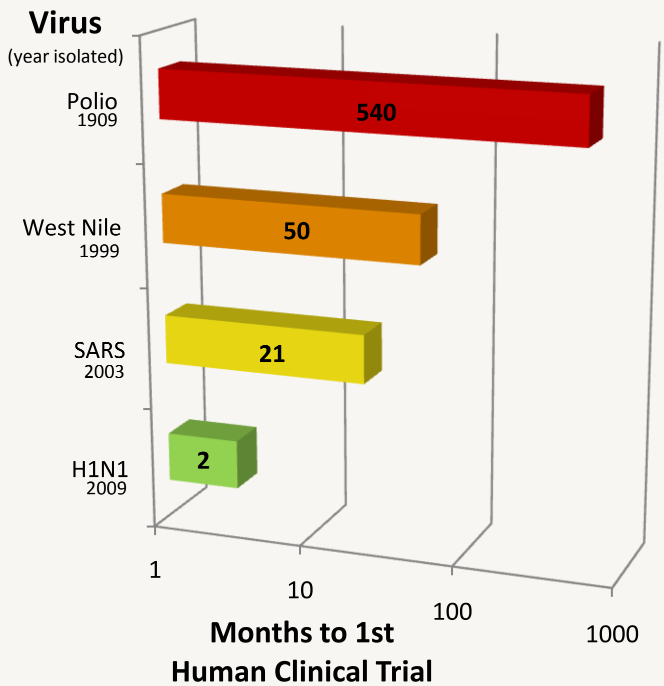
- The first discovery of West Nile Virus in the U.S. occurred in New York, in August, 1999.
- In 2003, a $3 million research grant by the National Institutes of Health (NIH) led to the first human vaccine trial.

SARS

- Discovered in China in November of 2002, the SARS virus was isolated in March, 2003.
- Just 21 months later, the first human clinical vaccine trials began at the National Institute of Allergy and Infectious Diseases (NIAID).

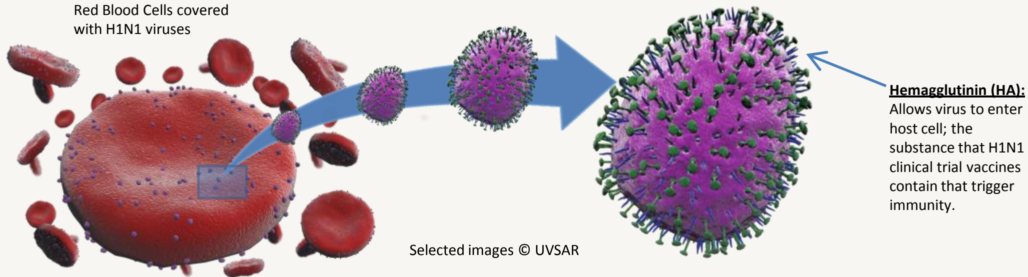
H1N1

- On April 2, 2009, a 5-year old boy in Mexico became the first patient diagnosed with H1N1 influenza.
- Only 2 months later, the NIAID announced that it had commenced human clinical trials for an H1N1 vaccine.



The NIH plays a crucial role in the global response to new viruses. The U.S. has contributed more than two-thirds of all new vaccines approved worldwide in the last 20 years. In the U.S., the NIH is the agency primarily responsible for pandemic influenza research. If the 2009 H1N1 virus mutates to become different from the current vaccine virus, the NIH is prepared to develop enhanced H1N1 vaccines to keep the world population safe.

NIH research on new production methods will further speed the vaccine manufacturing process.
Current vaccine technology involves growing the virus in chicken eggs, which is both limiting and time-consuming. With continued investment, the NIH can build more facilities and test more methods to create vaccines through cell-based vaccine development technologies.



Selected images © UVSAR

Prepared by
Association of American Universities
Updated 07/09/10

ASSOCIATION OF AMERICAN UNIVERSITIES
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"In the 21st century, disease flows freely across borders and oceans, and, in recent days, the 2009 H1N1 virus has reminded us of the urgent need for action." –U.S. President Barack Obama.

The President's call has been answered by the development of the 2009 H1N1 vaccine. Created at record-breaking speed, the vaccine is the latest example of how the NIH continues to build upon previous breakthroughs to advance the world's public health capabilities.

This is imperative, as immunization is one of the most successful and cost-effective health interventions that prevent disease.

"Over the past several years, the NIAID has conducted a major research effort that builds on long-standing programs related to seasonal influenza in order to improve our preparedness for pandemic influenza," states NIAID Director, Tony Fauci, M.D.

These efforts cannot be overstated, Dr. Fauci continues: "Results from these basic research studies lay the foundation for the design of new antiviral drugs, diagnostics, and vaccines, and are applicable to seasonal and pandemic strains alike."

The National Institutes of Health supports most of the basic research that leads to the development of vaccines. In 2009, the NIH invested more than $200 million in various types of flu research, including H1N1. As the primary funding source for most academic and industrial vaccine projects, the NIH has played a primary role in shortening the timeline of vaccine development. A large proportion of NIH funding goes to academic institutions to conduct basic research, which is a critical element of vaccine development.

The United States has been tremendously successful in vaccine research and development in the last 20 years. Even so, during this time of great success, vaccine development has often been hindered by inadequate investment. This could prevent the discovery of a missing piece of scientific knowledge or technology.

This investment shortage is particularly serious at a time when the costs of vaccine development have continued to increase, due largely to Good Manufacturing Practices (GMP), which were introduced into vaccine production in 1980. GMP standards play the important role of ensuring quality but also drives up the cost of investments in the researchers, clinical trials, facilities, and manufacturing critical to vaccine development. This is one very important reason that continued increases in research funding are essential.

The American Recovery and Reinvestment Act has provided the NIH with $10.4 billion in research funding, but this investment is available only until September, 2010. Without a significant increase in Federal Government investment in FY2011, the NIH will likely face a steep drop in funding.

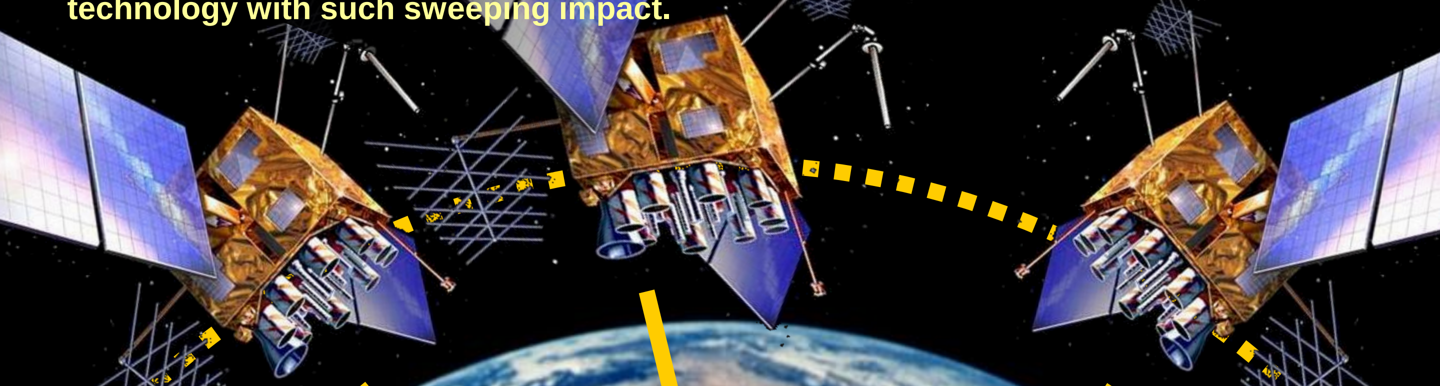
Speaking on the subject of decreased funding in FY2011, NIH Director Francis Collins has stated, "It's going to be tough, and anybody who has not realized the reality here needs to be prepared for what could be a very difficult time."

Our nation can continue to facilitate vaccine development through sustained, significant increases in our investment in the National Institutes of Health.

Basic Research Behind the

Global Positioning System

The Global Positioning System (GPS), a product of basic and applied research supported by the Department of Defense and other federal research agencies, reflects the spirit of our times: it helps us navigate the world and is closely tied to telecommunications and the Internet. Along with its importance to every branch of the U.S. military, GPS has numerous civilian applications. These include mapmaking, earthquake studies, air traffic control, automotive and boat navigation, archaeology, and commerce. GPS also saves lives—the technology can pinpoint a caller's location in an emergency and was vital to the rescue and recovery efforts following Hurricane Katrina and September 11. **When the basic research behind GPS began more than 50 years ago, no one could have predicted the development of a technology with such sweeping impact.**



Microwaves: GPS satellites send microwaves to a receiver, which measures how long it takes the signal to arrive. This information is crucial to helping calculate the distance between each satellite and the receiver. Microwave research was funded by the National Defense Research Committee, and later the Army and Navy, and performed by MIT, Harvard, and UC Berkeley scientists.

Radio navigation: Using a receiver's distance from each satellite, scientists are able to determine the receiver's location. This "Doppler shift" was first measured by MIT; further research was sponsored by the Air Force and performed at Johns Hopkins. The Air Force-sponsored Code Division Multiple Access System improved navigation by allowing satellites to broadcast on the same frequency without interfering with each other. This technique was first applied to the Navy's Transit satellite.

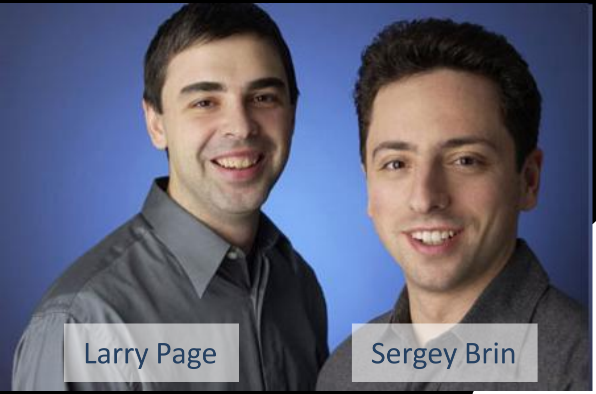
Atomic clock: The receiver and satellite use atomic clocks synchronized to the nanosecond. This technology would not be possible without Charles Townes' MASER research performed at Columbia and MIT. Research on atom trapping, sponsored by the Air Force and performed at Stanford, led to a 1000-fold increase in atomic clock accuracy. Columbia, Harvard, U. of Colorado at Boulder, and NIST have all built clocks using new materials, increasing accuracy even further.

Satellite: Launching technology was the result of research funded by the Navy, the Atomic Energy Commission, and NASA, and performed at U. of Iowa and California Institute of Technology. Research for a low-cost GPS design was funded by the Air Force and performed by a Texas A&M professor. The final design combined Air Force- and Navy-sponsored research.

Produced by the Association of American Universities, www.aau.edu, July 2010

Investments in Basic Research Today…

The question facing our country is not whether we can afford to fund basic research. The question is, can we afford not to?

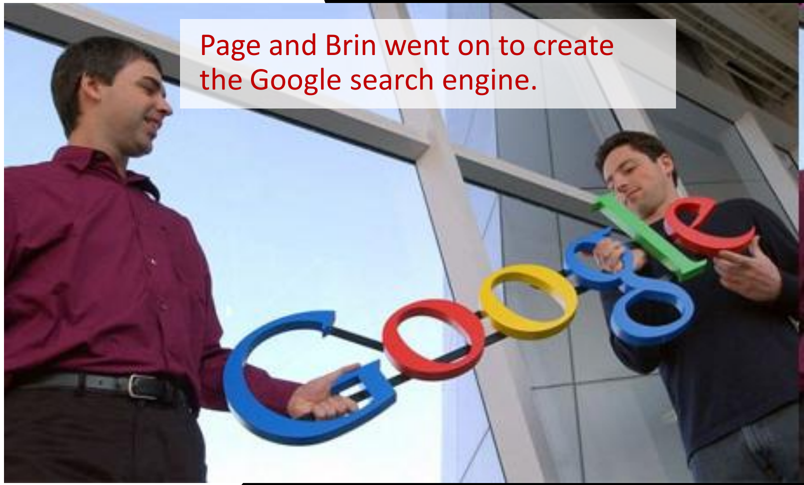


The Funding

In the Mid-1990's, two graduate students, supported by a portion of a **$4.5 million digital libraries research grant from the National Science Foundation** (NSF) to Stanford University, sought to better understand, sort and find information using the World Wide Web. These students were **Larry Page and Sergey Brin (**an NSF Graduate Fellow).

The Technology

Through their research at Stanford, Page and Brin developed a prototype search engine, which depended on their innovative **PageRank Method.** This method produced better search results by calculating rankings based on linkages by previous users from each page to other pages. PageRank is still used in their search engine service today, known throughout the world as Google



The Return-on-Investment

Today, Google has **19,604 full-time employees** and is worth almost **$150 billion.** It all began with a **$4.5 million** National Science Foundation grant.

The return-on-investment is greater than the ratio of this red dot to the white circle.

…generate the knowledge and talent that will fuel our future.

--Association of American Universities, July 2010


Automotive Applications of Basic Research
Federally funded research laid the foundation for many technological advances contained in the modern car
LCD Monitors
Speech Recognition Technology
Lithium-ion Batteries
Catalytic Converters
Synthetic Polymers
Shatterproof Windshields
Adjustable Seats
Center Brake Light
Airbag Deployment Sensors
CD Players
GPS
Transistor
Remote Car Locks
Extended Tire Life
Car Bumpers

LCD Monitors: NIH, NSF, and DOD funded the basic liquid crystal research that led to the creation of thin film transistor liquid crystal displays (LCD) in 1988. The thinner displays make possible such in-car features as back-up cameras, television, DVDs, video games, and GPS.

Speech Recognition Technology: NSF and the Defense Department's DARPA funded initial research in the 1980s leading to the development of speech activation and recognition technology. The technology is used to control music, navigation, and phone devices for safer driving.

Lithium-Ion Batteries: The rechargeable lithium-ion (Li-ion) battery, developed in 1990, stemmed from DOE basic research funding in electrochemistry. The Li-ion battery is an energy-efficient alternative for powering hybrid and electric cars. This battery allows for the extended range capabilities in the 2011 Chevrolet Volt.

Catalytic Converters: Supported by NSF, Art Heuer at Case Western Reserve University developed zirconium dioxide-based ceramics while researching ceramics capable of surviving extreme conditions. Used in catalytic converters in the car exhaust system, these strong ceramics increase gas mileage by preventing cracking.

Synthetic Polymers: In the 1950s, NSF funded researchers at the University of Akron studying durable forms of rubber. These researchers were able to transition to other synthetic polymers, resulting in many applications such as automotive components.

Shatterproof Windshields: Neutron-scattering instruments funded by DOE allow researchers to study the structure of various compounds. This research has contributed to the development of polymers, including polyvinyl butyral, which is the resin used to create shatterproof glass.

Power windows: Neutron-scattering instruments funded by DOE allow researchers to study the structure of various compounds. This research has led to the development of new types of magnets, which are a critical component of the small yet powerful motor used to raise and lower car windows.

Center Brake Light: In 1974, social scientist John Voevodsky found that a third brake light resulted in 60.6% fewer rear-end collisions, 61.1% fewer injuries to drivers, and 61.8% less in repair costs. After finding similar results in a repeat study, the National Highway Traffic Safety Administration now requires the third brake light.

Semiconductors: Though semiconductors first appeared around 1900, it wasn't until the development of basic research into quantum mechanics that scientists could understand this phenomenon and begin to improve semiconductor design. Today, semiconductors are the key component of every computer chip, including the chip that handles everything in a car from the fuel efficiency to the power steering to the air conditioning.

Airbag Deployment Sensors: Micro-electro-mechanical systems (MEMS) allow for the creation of tiny motors used in airbag deployment sensors. Both NSF and NASA funded basic and applied research on MEMS accelerometers, a critical component in triggering airbags.

Remote Car Locks: Basic research supported by DOE's Office of Science contributed to the development of non-rechargeable lithium batteries, which offer high energy storage capacity. These batteries are used in remote car locks to ensure their long life.

CD Players: CD players rely on data compression algorithms, the product of NSF-funded exploratory research. Irving Reed, Gustave Solomon and Elwyn Berlekamp at UC-Berkeley created the codes and algorithms that led to many applications, like the CD player, decades later.

Tire Performance: NSF has fostered development of nanoscience by leading the National Nanotechnology Initiative (NNI) and investing in university research. Nanotechnology breakthroughs include high-performance rubber additives for tires, such as Nanoprene.

Global Positioning System (GPS): The development of GPS technology utilized basic and applied research (microwave research, recognition of the Doppler Shift, atomic clocks, satellite launching technology) supported by DOD and other federal agencies and carried out at universities.

Car Bumpers: Reaction injection molding (RIM) creates resilient plastics used in car bumpers, resulting in reduced repairs, insurance costs, and fuel consumption. RIM research came out of university-based materials research laboratories, funded by DOD, NSF, and NASA.

> *"The limitation of focused or problem-oriented research becomes apparent in the following observation: If you know what you are looking for, you are limited by what you know."*
>
> --Nobel Laureate Jerome I. Friedman, MIT physics professor

Produced by the Association of American Universities, www.aau.edu, September 2010

Diagnostic Tools and Treatment:

Basic Research Saves Lives

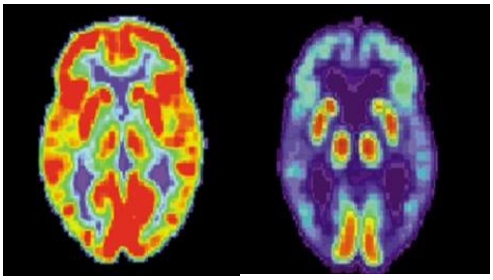
The medical imaging technologies that hospitals and clinics use routinely for diagnosing injuries, illnesses, and diseases were just science fiction 50 years ago.

It took the dedicated work of physicists, chemists, biologists, engineers, and others to turn scientific theories into the technologies and medical equipment we rely on today. These researchers were supported with funding from the National Institutes of Health (NIH), Department of Energy (DOE), National Science Foundation (NSF), National Institutes of Standards and Technology (NIST), and Department of Defense (DOD).

Diagnostic Tools Made Possible by Government-Sponsored Basic Research

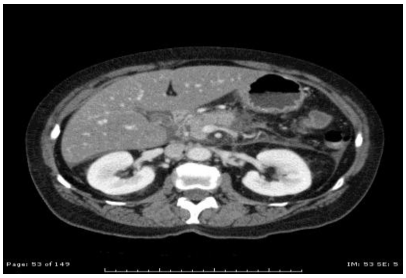
Positron Emission Tomography (PET)

PET uses a specialized camera to measure the concentration and movement of radiotracers, or radioactive atoms, in the human body, aiding the diagnosis of such diseases as Parkinson's and Alzheimer's. DOE and NIH supported the initial research behind PET technology and continue to support research to advance its capabilities today.



These images of a normal brain (left) and one with Alzheimer's disease (right) were taken with PET cameras.

Images courtesy of **www.nia.nih.gov**



This CT scan of a liver, which pictures everything from the organ itself to its surrounding blood vessels, can help doctors detect blocked ducts, tumors, and other abnormal tissues.

Image courtesy of www.mritutor.org

Computed Axial Tomography (CT)

CT uses sophisticated computer technology to produce 3D images of the skeleton and internal organs, significantly reducing the need for exploratory surgery to diagnose disease. Since the 1970s, NIH and DOE have provided funding for the research behind CT. Today, NIH is funding research to reduce the amount of radiation in CT scans.

Magnetic Resonance Imaging (MRI)

MRI, which is useful in detecting damage to the body's soft tissues, was developed from basic research on atomic nuclei funded by NIH, NSF, and DOE beginning in the 1970s. Scientists researching the magnetic characteristics of atoms discovered that their nuclei act as if they are polarized magnets. MRI detects those polar properties with cameras to display pictures of the human body.

This MRI of a knee (left) can help doctors detect damage to fragile tissue caused by accidents, stroke, bone disease, and tumors.

Image courtesy of www.MR-TIP.com

Basic Research: Benefiting Patients, Revolutionizing Medicine

The U.S. has been the world leader in scientific discovery and medical innovation for more than 60 years. Discoveries made through government-funded basic scientific research have led to the creation of thousands of high-paying American jobs and to life-saving therapies and treatments that benefit millions of people. However, without increased investment in basic scientific research, U.S. leadership is at risk.

PET

- A 52-year-old male with cognitive problems was referred for a PET scan to evaluate brain metabolism.
- The PET scan revealed several areas of his brain to be consistent with patterns of Alzheimer's Disease, allowing for a confirmed diagnosis and potential treatments.

CT

- Three weeks after swallowing a dental crown, a 39-year-old woman was referred for a CT scan, which confirmed that she had aspirated a foreign object.
- Incidentally, the scan also revealed a nodule in the patient's right lung, later diagnosed as lung cancer.

MRI

- A 23 year-old male twisted his right knee while playing football.
- After initial conservative therapies failed to improve his injury, he was referred for an MRI scan that revealed a complete tear of the anterior cruciate ligament.

The case studies at left illustrate the revolutionary care that medical diagnostics provide as a result of discoveries in basic science. Federal support of basic research has improved American lives over the course of history. Only continued investments will yield the next generation of innovative technologies and the scientists and engineers who will produce them.

Physicians Rank MRI and CT as Most Important Medical Innovation

Many technological innovations have had great clinical significance in U.S. medicine. However, when asked in a 2001 survey to rank the value of 30 top medical innovations over the past three decades, physicians cited MRI and CT diagnostic interventions as providing the greatest benefit to their patients. Ranked higher than other drugs and medical tests developed during this period by a considerable margin, the basic-research-rooted MRI and CT have transformed modern medicine.

The nation's investments in basic research in a variety of disciplines – including biology, chemistry, physics, engineering, and more – are critical to America's continued global leadership in innovation, improved health, and the quality of medical care and treatment. Though these investments may take years or decades to ripen, history has shown their unequivocal link to competitiveness and to the wellbeing of the American people.

Federally Funded Basic Research

Making the Invisible, Visible Through Infrared Technology

What is infrared?

Infrared radiation (IR) is emitted from all heat-producing objects. Infrared imaging is the detection and imaging of this heat emission.

Image: Courtesy of NVESD

AIDING U.S. TROOPS

The US military uses infrared imaging technology, or Night Vision, to enable soldiers to see better in darkness. It was used extensively in Vietnam and Operation Desert Storm. IR technology is also deployed in weapons, such as "heat-seeking" missiles.

IMPROVING ENERGY EFFICIENCY

IR imaging improves household energy efficiency by detecting locations of heat loss (See right side middle).

Image: Courtesy of JPL

UNDERSTANDING THE UNIVERSE

Astronomers use infrared imaging to detect heat-emitting objects- both invisible and visible objects- in space. It has added dramatically to our knowledge of the early universe.

HISTORY OF IR TECHNOLOGY

Federally sponsored basic and applied research at the Department of Defense, the National Science Foundation, USDA, and NASA made modern IR technology possible. The Army's Night Vision and Electronic Sensors Directorate played a key role in early IR technology development. Today IR technology has numerous security and civilian applications.

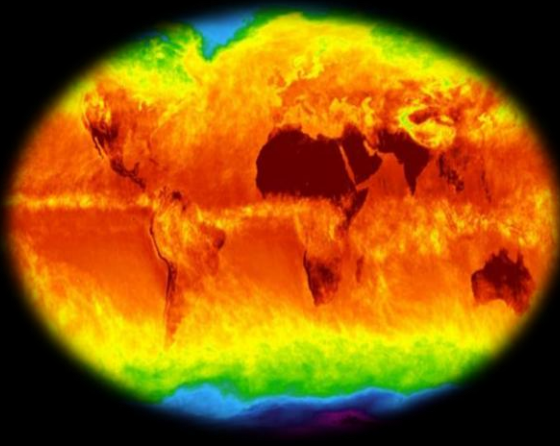


Image: Courtesy of JPL

OBSERVING CLIMATE CHANGE AND WEATHER

Infrared imaging is used to observe land and ocean temperature, weather, plant and animal growth, migration patterns, and pollution. IR satellite images provide the most up to date storm conditions, and they are a vital tool in observing climate change phenomena such as glacial melting and overall atmospheric fluctuations.

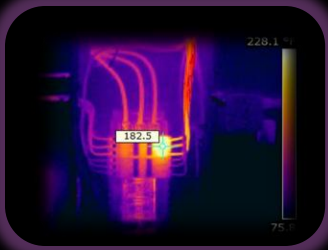


Image: Courtesy of KSV

PROVIDING SAFETY IN THE HOME

IR sensing equipment is used to detect possible fire hazards from electrical equipment, which heats up before it fails. Firefighters also use IR imaging to detect fire sources.

Image: Courtesy of Reece Builders

Image: Courtesy of Caltech

DETECTING DEADLY DISEASES

IR imaging is an effective technology for breast cancer, arthritis, diabetes, tumors, and other physical ailments.

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