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PRIORITY-SETTING IN U.S. SCIENCE POLICIES

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About VINNOVA

VINNOVA, Swedish Governmental Agency for Innovation Systems.

VINNOVA´s mission is to *promote sustainable growth*
by funding *needs-driven research*
and developing *effective innovation systems*.

Through its activities in this field, VINNOVA aims to make a significant contribution to Sweden´s development into a leading centre of economic growth.

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Research and Innovation for Sustainable Growth.

Priority-Setting
in U.S. Science Policy

by

Kerstin Eliasson

VINNOVA´s Foreword

VINNOVA is the Swedish Governmental Agency for Innovation Systems and has a mission to promote sustainable growth by funding needs-driven research and developing effective innovation systems. The principles and institutional mechanisms utilized in setting priorities for public financing of research and development are crucial aspects of any country's research and innovation system. As an input to the development of its own strategies and positions, VINNOVA has decided to commission in-depth studies of the prioritization mechanisms in the U.S., China and Japan and in the EU framework programs. Welcoming open discussions on issues relating to priority-setting and hoping that the studies may also be of interest to other institutions in Sweden and internationally, these are published in English and made generally available. The project is managed by Göran Pagels-Fick at VINNOVA's Strategy Development Division.

This report covers priority-setting in the U.S. It was written by Kerstin Eliasson who has reported on science policies in the United States for many years and served as science counselor in the Swedish Embassy in Washington, D.C., 2000-2004. Kerstin Eliasson is a former Deputy Minister for Higher Education and Research in Sweden. She is currently on the board of the Joint Research Centre of the European Commission and a member of the Strategic Forum on International S&T Cooperation of the European Union.

The author brings into focus the pluralistic nature of the American research funding system and the dominating bottom-up priority-setting mechanisms. It is thus an impossible task to give a comprehensive account of the entire priority-setting mechanism at national level, so Eliasson has chosen to paint the big picture, giving particular insights about the way priority-setting is being carried out at two institutions: the National Science Foundation (NSF) and the National Institutes of Health (NIH). Eliasson observes that "some argue that the mission-oriented perspective, which is really prevalent in the American system, is the key to the success of U.S. science. When such a perspective is prevalent, there is a lesser need to argue about the importance of basic versus applied research." The report contains many such observations, recognizing the institutional differences between American and Swedish research funding mechanisms while simultaneously providing stimulating food for thought on the effectiveness of the Swedish model.

VINNOVA, November 2009

Göran Marklund
Director and Head of Strategy Development Division

Author´s Foreword

This report will focus on priority-setting in science policy in the United States.

An attempt will be made to describe the U.S. system and to clarify whether priority-setting in science policy plays a role in the overall successes of American science and competitiveness. Are there any crucial factors in priority-setting which have a major impact on the quality of science and for innovation and competitiveness?

The American science system is a large and complex structure with a loose coordination of efforts. Many levels of government, many units within each level, and many stakeholders – both as performers and as users – are involved in decision-making at different levels and many give input to the process of priority-setting.

To describe this system and priority-setting within it is not an easy task. I also want to stress that this is not an academic report on the issue. It is based on some written documents and on interviews made mainly at the National Science Foundation but also at the National Institutes of Health, as well as with representatives of the Office of Science and Technology within the White House and the American Association for the Advancement of Science.

In 2004, a report was published by the Institute for Growth Policy Studies in Sweden on American Science Policy. It was an assignment from the Swedish Ministry of Education and Research. That report gave an overview of the science system and science policies in the United States at the time. One part of that report has been somewhat modified and included in this one as a summary. It concerns the historical development of the science system in the U.S.

I am grateful to my American friends who have taken time to meet with me in Washington, D.C. during my visit mid-March to mid-April 2009 and to those who also have assisted me in reading the draft report. In particular Dr. Irwin Feller, Professor Emeritus of Economics at Pennsylvania State University, gave very useful comments and advice. Special thanks to Dr. Ann Carlson at the National Science Foundation who contributed substantially to this report by providing facts and figures as well as very valuable comments and thoughts. The conclusions, however, are my own.

Kerstin Eliasson
Stockholm, October 2009

Contents

1 Development of the American Science System

In order to understand the present American science system and policies, it might be helpful to sketch out its historical evolution and give a few facts about its development over time.

At the end of the 19th Century there were nine colleges in the U.S., all located on the American East Coast. These early colleges were private institutions, emphasizing a classical education. By mid-century, a number had expanded their curriculum to include engineering or science, laying the foundation for their subsequent evolution as centers of science and research. Following the Morrill Act of 1862, this trend was boosted by the establishment of the land-grant system of colleges and universities, with their emphasis on applied science and technology. To spur the States to invest in education and research, Congress also adopted the Land-Grant College Act. States were given free land in exchange for creating colleges benefitting agriculture and the mechanical arts.

This was the origin of the complicated mixture of public and private support for the higher education system in the United States. Private universities also became involved as some States chose them to provide education in agriculture and mechanics. One of those was Cornell University in the State of New York. Cornell operates three colleges and one school on behalf of New York State.

Still, viewed historically, the advent of what is now seen as the paradigmatic American system of research-intensive graduate universities is largely a product of the 20th Century. As noted by one historian: “Between 1880 and 1890 only and handful of institutions in the United States had legitimate claims to being a ‘real university’. Apart from Johns Hopkins, Cornell, Harvard, Clark and Columbia, the list of serious contenders was slim” (John Thelin, “A History of American Higher Education”).

Prior to the establishment of Johns Hopkins, Clark and some of the others mentioned above, U.S. scientists went to Europe for their training, where the scientific frontier was at the time. However, American research was later strengthened by the influx of European researchers, particularly around the time of World War II.

Toward the end of the 19th Century, the United States had become the world’s leading industrial nation. American companies started to establish their own R&D laboratories. The first such laboratory was established in 1901 and by around 1920 some 400 companies had their own laboratories. Many of these laboratories were to be found in chemical companies. Even so, industry was also involved in the institutions of higher learning in many ways. Several industrialists donated large sums of money to build new universities, create foundations and support charitable causes. This was the case for Rensselaer Polytechnic Institute, Brown University, University of Chicago, and Stanford University among others.

This was the beginning of a distinct business, namely fund-raising at universities and colleges (private and public), an activity generally known as development. Every year, alumni give large contributions to institutions of higher learning.

Universities and colleges were very dependent on private funding at the time. The States provided appropriations for public universities and some applied research. The Federal Government provided nothing for instruction and only limited amounts for research, mainly in agriculture. Industry was the dominant partner for universities. This cooperation was not without conflict as industry had views on the management of universities and the direction of research.

> *"In 1900 the universities, grown in one generation from colleges with narrow courses of studies, seemed to have become the natural homes of disinterested, pure science…. The Research was a division of labor which gave rise to the assumption that basic research belonged to the universities, leaving only applied research to the Government… Although the split between basic research and the common concerns of society was noticeable fairly early in the 19th Century, it became institutionalized in the division of functions between Government and the universities"*
>
> (Hunter Dupree, "Science in the Federal government").

Before 1940, the Federal Government accounted for no more than 12 to 20 percent of total R&D investment in the United States and as much as 40 percent of that went to agricultural research.

World War I had profound effects on every part of American science, whether supported by the Government, the universities, or the foundations. The first major result was the infusion of research into the economy, especially production; this was so thorough that industrial research as a branch of the country's scientific establishment dates its rise to eminence almost entirely from the war period (Dupree).

The period between World War I and World War II can be characterized as a time when Federal interest in research and development waned. The Depression had profound consequences for academic R&D. During World War II, the Federal Government increased its investment in research as well as basic research. Developments after the War, the Cold War period, further strengthened the involvement of the Federal Government in research. National security needs promoted this investment. The share of government funding of total R&D rose from less than 20 to 75 percent in five years. Also, an increasing proportion of federal funding went to universities and companies as contract research whereas before the War resources were mainly given to federally owned institutions. By 1960, federal research investment in academia had reached 60 percent of total academic funding.

Even if funding for some civilian research areas has increased in recent years, notably for medical research, the proportion devoted to defense research has been continuously strong in the federal budget during the latter half of the 20th Century, and consumes 58.5 percent of the total R&D budget today. World War II spurred the installation of national laboratories in physics and engineering. These laboratories are financed from the budget of the Department of Energy.

The launch of Sputnik by the Soviet Union led to the creation of the National Aeronautics and Space Administration (NASA) in 1958. It also resulted in the reestablishment of a Science Advisor to the President and to the creation of The Defense Advanced Research Projects Agency (DARPA). This agency was established to support interdisciplinary research across the three military branches. DARPA is often looked upon as a good example of flexible research funding in the United States.

From 1950 to 1960, military expenditure rose from USD 12.9 to 39.2 billion.

During the 1960s and 1970s, however, it was felt that American research was too dominated by defense research and that there were other pressing societal needs which should benefit from investment in research such as poverty, poor health and a deteriorating environment. By the mid-1960s, the proportion of defense-related research had decreased to 50 percent of total federal R&D spending. The decreased spending on defense R&D also meant that the role of the Department of Defense (DOD) in academic research diminished. In 1958, the DOD accounted for 44 percent of total federal expenditures for research in academia. In 1965, this share was down to 21 and in 1980 to 9 percent.

When Ronald Reagan was elected President in 1980, defense expenditure increased dramatically, particularly for the Strategic Defense Initiative. Defense R&D also increased and made up 75 percent of total federal R&D expenditure. However, the fall of the Berlin wall changed the picture completely. During the late 1980s and early 1990s, the United States was preoccupied with the economic competition from Japan. Technology transfer became the key objective. All federal agencies were supposed to engage in activities that benefited the American economy. This was also the time when some universities started to engage more intensively in tech transfer and commercialization of research results.

As is clear from the above, defense-related R&D has been very strong in the United States since World War II, even if it has fluctuated quite a bit. The other unique characteristic of the American system is the heavy increase in spending on health-related research which took place from 1997 to 2004. The budget for the NIH now amounts to USD 40 billion, including the Stimulus Package [American Recovery and Reinvestment Act (HR 1; PL 111-5)], which was signed into law by President Obama in February 2009.

The federal engagement in medical research originated through the needs of the military during the 18th and 19th Centuries. The National Institute of Health came into being in the 1930s and was supposed to function as a medical research council, not only funding its own laboratories. In 1937, the National Cancer Institute (NCI) was formed. The National Institute of Health later became the National Institutes of Health (NIH) and other institutes were also created. There are now 27 institutes and centers of the NIH, and the Office of the Director. For historical reasons, the NCI has a special position within the NIH. The Director of the NCI is the only director of an NIH institute appointed by the President. The NIH Director is also appointed by the President and confirmed by the Senate.

The budget of the NIH increased rapidly to more than 1 billion in the mid-1960s. The so-called extramural support, i.e. support mainly to academic institutions outside the NIH but also to industry and non-profit foundations, had grown to 1 billion in the mid-1970s. As previously pointed out, the budget of the NIH currently amounts to USD 40 billion, with more than half of its research budget typically devoted to academic research.

The major investment in defense R&D and biomedical research were and are still made mainly to achieve a specific mission, i.e. for national security and public health reasons. However, a substantial amount of basic research is financed as part of those missions and the National Science Foundation (NSF), the only agency with the sole mission to support basic research as well as science and engineering education across all fields, was created in 1950.

Up until World War II, support for basic science was not prevalent and American science and research not as prominent as in Europe. The War changed this situation when many scientists fled from Germany and other European countries to the United States. After the War there was a debate in the U.S. about the control of science and research. In 1941, Dr. Vannevar Bush had become Director of the newly established Office of Scientific Research and Development (OSRD) under President Roosevelt. OSRD was responsible for coordinating federal research investment. In his famous report to President Truman of 1945, “Science the Endless Frontier”, he presented his proposal for a National Research Foundation. The main ingredients were the establishment of a research council for basic research in all areas, including military and medical research, and the idea of leaving decisions about the direction of research to the scientists. Bush also believed there was no great need for extensive coordination of the federal research effort.

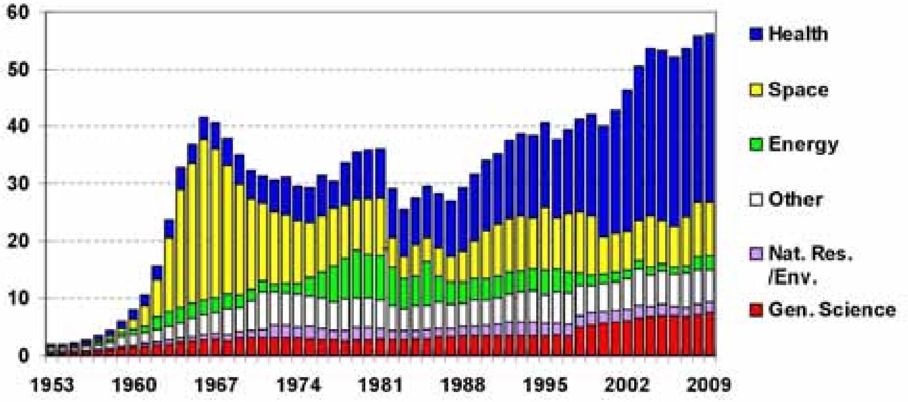
After several years of discussion, the National Science Foundation was established and Bush's ideas largely adopted. However, defense-related research had become so large at the time with the creation of separate institutions to fund defense R&D, that defense-related research and development was left out of the NSF. By the time of this debate though, several agencies, as well as the NIH, had established lines of support for basic research aligned to their mission objectives. Thus, the idea of having one central agency responsible for cross-agency basic research received little political support. In 1954, Congress decided that other federal agencies could finance basic research as well.

In fact, the most important funding source of basic research in the U.S. is the NIH. In 2009, the NIH was funding 53 percent of total federal support for basic research compared to 15 percent for the NSF. Even so, the NSF is the only federal agency, which has the support of basic research as its main mission. This support covers all research areas except the humanities. Although the NSF budget only represents 4 percent of the total federal budget for research and development, the NSF provides more than 40 percent of the federal support for non-medical basic research at the colleges and universities of the United States.

The argument can thus be made that support for science and research in the United States has not been guided by an objective to support science for science's sake but has mainly been driven by other motives or missions. This, of course, does not mean that basic research in the U.S. is different from that in other countries. The mission-oriented perspective also affects the balance between different kinds of basic research, i.e. between areas. Another balance might have been struck if the NSF had been the main supporter of basic research in biomedicine.

It is sometimes argued in the United States that organizational reforms of the science system, such as creating a special ministry of science and technology or completely new agencies, which are frequently made in other countries, could never occur in the U.S. The size and complexity of the United States and the traditional mission-oriented perspective in science make such changes unlikely. However, when major threats occurred, as they did during World War II and when the Soviet Union launched Sputnik, major changes in priorities took place even though the science system did not change that much. This was also true after the terrorist attacks on September 11, 2001 after which a new department was created, the Department of Homeland Security.

Figure 1. Trends in nondefence R&D by function, FY 1953-2009 (outlays for the conduct of R&D, billions of constant FY 2008 dollars)



Source: AAAS, based on OMB Historical Tables in *Budget of the United States Government FY 2009*. Constant dollar conversions based on GDP deflators. FY 2009 is the President's request.

Note: Some Energy programs shifted to General Science beginning in FY 1998.

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2 Some Facts about the Current Science System and Policies in the United States

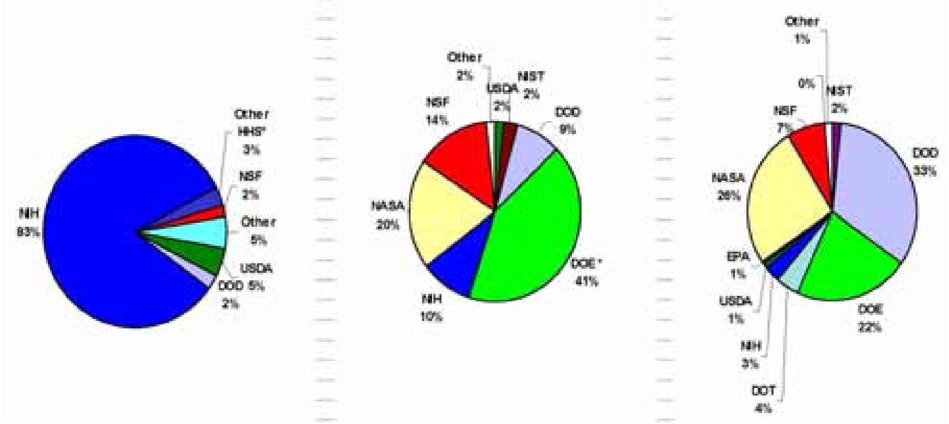
For decades, the United States has been the leader of the world in science and still is. This can be seen from the volume of resources, number of scientific publications and citations, number of Nobel laureates, comparative ranking of universities, number of doctorates in science and engineering in the workforce, and patents. The U.S. is also the undisputed leader in applying research and innovation to improve economic performance. The report "Rising above the Gathering Storm" (National Academies, 2007) refers to the IMD International World Competitiveness Yearbook 2005 where the U.S. is ranked first in economic competitiveness.

As was stressed at the very beginning of this report, the American science system is a large and complex structure with a loose coordination of efforts. Many levels of government, many units within each level, and many stakeholders are involved in decision-making at different levels and many give input to the process of priority-setting.

Part of this complexity is that there is no single research budget in the United States. Federally funded science and research, including basic research, is financed through the overall budgets of 24 federal departments and independent agencies where R&D investment must compete with investment for other purposes. Information about the total level of R&D is only reached after Congress has decided upon the budget for each agency and the different sub-items within those budgets.

Many departments and agencies are involved in promoting different missions and supporting different disciplines. This makes it even harder to achieve centralized control and policy-setting.

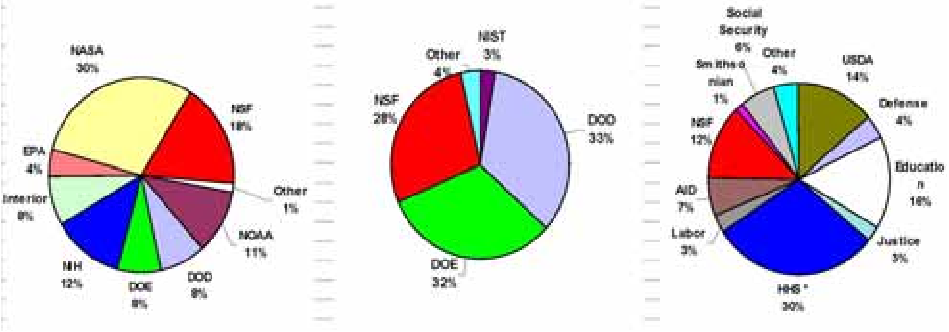
Figure 2. Federal funding of research by agency and discipline, FY 2005 (preliminary obligations)



Life Sciences **Physical Sciences** **Engineering Sciences**

Source: National Science Foundation, Federal Funds for Research and Development FY 2003, 2004 and 2005, 2006. Data exclude development.

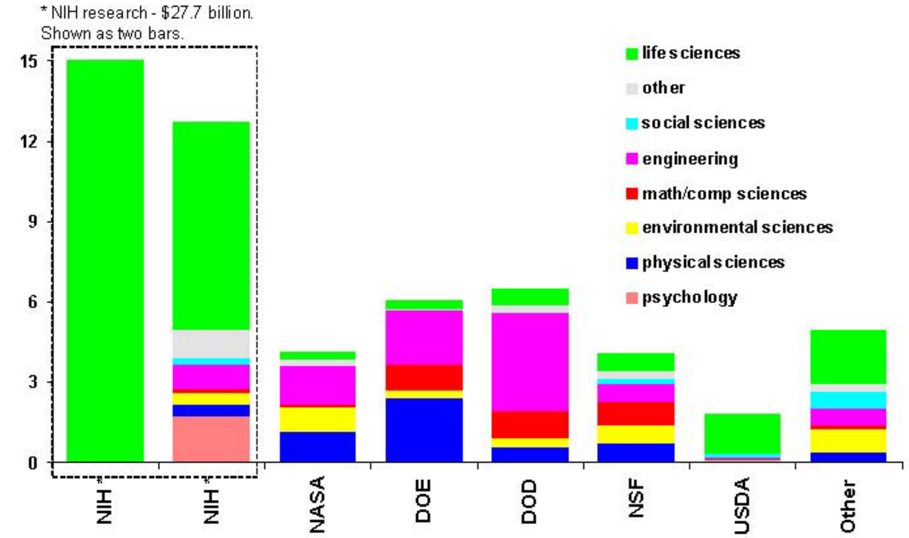
Figure 3. Federal funding of research by agency and discipline, FY 2005 (preliminary obligations)



Environmental Sciences **Computer Sciences*** **Social Sciences**

Source: National Science Foundation, Federal Funds for Research and Development FY 2003, 2004 and 2005, 2006. Data exclude development.

Figure 4. Federal research by discipline at selected agencies, FY 2007 (preliminary obligations in billions of dollars)



Source: National Science Foundation, *Federal Funds for Research and Development Fiscal Years 2005, 2006 and 2007,* 2008. Development and R&D facilities excluded. FY 2007 data are preliminary.
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According to the National Science Board ("A Companion to Science and Engineering indicators 2008"), the United States was spending about USD 340 billion on R&D in current dollars. In 2007, the Federal Government accounted for 26.7 percent, industry 66.6 percent, universities and colleges 2.7 percent, other nonprofit institutions 3.2 percent, and non-federal government 0.9 percent.

Of total federal spending for research and development (R&D) in the President's 2009 budget, 58.5 percent goes to defense-related R&D and 41.5 to civilian R&D. Basic and applied research each account for approximately 20 percent of the total, and development for 58 percent and approximately 3 percent (numbers do not total 100 due to rounding error) is R&D facilities and capital equipment.

The Department of Defense is the largest funder of federal R&D (although it should be noted that it does not fund the entire amount of the "defense-related R&D noted above"), followed by the National Institutes of Health, The National Aeronautics and Space Administration, the Department of Energy, the National Science Foundation, Department of Agriculture, Department of Commerce, and the Department of Homeland Security. Taken together, these eight agencies fund approximately 98 percent of federal R&D. The National Institutes of Health is the largest funder of basic research, followed by the National Science Foundation, the Department of Energy, NASA, and the Department of Defense, which together account for 93 percent of total federal funding for basic research.

Research in the U.S. is also conducted by a variety of sectors. Industry carries out approximately 67 percent of all U.S. R&D, followed by universities and colleges (13%) the Federal Government (7 percent), non-profit organizations (4 percent) and federally funded research and development centers (FFRDCs) (4 percent). Of federal funds for R&D, approximately 40 percent is obligated to business and industry, 22 percent to the Federal Government, 21 percent to universities and colleges, 8 percent to FFRDCs, and 5 percent to non-profits.

According to the NSF's Science and Technology Indicators for 2008, academic R&D approached 0.4 percent of the U.S. Gross Domestic Product (GDP) in 2006, and is estimated to account for 56 percent of U.S. basic research. The Federal Government provided about 63 percent of academic R&D while the institutions themselves provided about 19 percent. The contribution from business and industry was approximately 5 percent. State and local governments are another important source of academic R&D funding, particularly for public institutions. The top 100 research universities (of around 650) received approximately 80 percent of federal funds.

> *"Innovation or funding basic research for future economic competitiveness has not been an explicit mission, though it is often stated as the primary rationale for federal support of research"*.
> (Kei Koizumi, AAAS in "Science, Technology, and the Federal Budget", September 23, 2008).

However, innovation has lately become a strong priority in the U.S. A number of recent studies and actions address this topic. The National Academies "Rising Above the Gathering Storm" (2007) and the Council on Competitiveness' document "Innovate America" (2005) formed the intellectual background for the America COMPETES Act of 2007. The Act authorizes increases in the nation's investment in science and engineering research at the National Science Foundation, National Institute of Standards and Technology (NIST) laboratories, and Department of Energy (DOE) Office of Science. Supporting the objectives of the America COMPETES Act, it is interesting to note that the National Science Foundation has invested in a program on the Science of Science & Innovation Policy (SciSIP). This program supports research designed to advance the scientific basis of science and innovation policy. Research funded by the program thus develops, improves and expands models, analytical tools, data and metrics that can be applied in the science policy decision-making process.

Betting further on the potential of R&D to stimulate innovation and competitiveness, the stimulus bill of 2009 includes an additional USD 21.5 billion in R&D; USD 18 billion for the conduct of R&D and USD 3.5 billion for R&D facilities and capital equipment. The National Institutes of Health received the largest portion, USD 10 billion, of this stimulus funding, followed by the Department of Energy (USD 5.5 billion), the National Science Foundation (USD 3 billion), the Department of Commerce (USD 1.4 billion), and NASA (USD 1 billion).

3 History of Priority-Setting in US Science

This brief account on the history of priority-setting in R&D in the United States is based on a study, “A strategy for Assessing Science: Behavioral and Social Research on Aging” (National Academies Press, 2006. Editors: Irwin Feller and Paul C. Stern). Although this study focuses on a specific area within the realm of the NIH, the presentation and the arguments are valid and cover priority-setting in general.

The study refers to a surge of policy attention to the issue of priorities in the early 1960s, when R&D investment rapidly grew. Alvin Weinberg’s articles about the “Criteria for Scientific Choice” drew attention from the National Academy of Sciences (NAS), from the National Research Council (NRC) and to a certain extent also from Congress, and the NSF. The criteria defined by Weinberg were internal and external criteria: the readiness for exploitation and degree of competence by the scientists were internal whilst external criteria covered the technological, scientific and social merit of research in specific fields.

It is stated that policy attention waned after the 1970s, due to such factors as difficulties in moving from general agreement on criteria to operationalizing them. There also seems to have been little consensus in the U.S. concerning the reliability and validity of techniques to assess the relative importance of different fields. Another reason for the decline in attempts to apply systematic criteria could also be traced to the unwillingness or inability of the scientific communities to agree about priorities in their fields.

What was accepted at the time, however, was the notion that there was a distribution of roles and power between the highest political level and the agency level and the peer or merit review systems. Consensus also included the desirability of maintaining some balance among fields in support for science, especially between the life sciences and the natural sciences and engineering. According to the study, there was no deeper analysis to justify policy choices, such as the relative apportionment of funds among disciplines and fields.

A lot of attention was given to overall levels of science, rather than the distribution across various fields. There was a widespread notion that the system should not be changed as it had proven to give the United States a preeminent position in world science, even if there was a lack of evidence about its effectiveness.

In the 1990s, there was increased attention on the issue of priority among scientific fields. The reasons for this were a growth in research expenditure which called for more accountability, and competition for funds between research and other policy areas. In the early 1990s, every government agency was obliged to comply with the Government Performance and Results Act (GPRA). Agencies were requested to develop multi-annual strategic plans, defining objectives and demonstrating how these objectives had been reached. Implementation of GPRA was further defined in the Performance Assessment Rating Tool (PART).

According to the study, another reason for the increased focus on outputs and outcomes was advances in the assembly of and access to quantitative data. This resulted in an expansion and refinement of such things as the NSF’s science and engineering indicators. Other initiatives were the new data sets of U.S. patents linked to publications and advances in data mining and data visualization techniques.

Finally, a consensus emerged that the greatest opportunities for scientific breakthroughs lie in cross-disciplinary research but that the organization of government agencies and their working methods may not be conducive to fostering such research. Selection of research awards may be too conservative and risk-averse. Also, increasing globalization and competition from abroad makes the ability to judge where to make research investment even more desirable.

4 Current System of Priority-Setting

4.1 The Highest Political Level

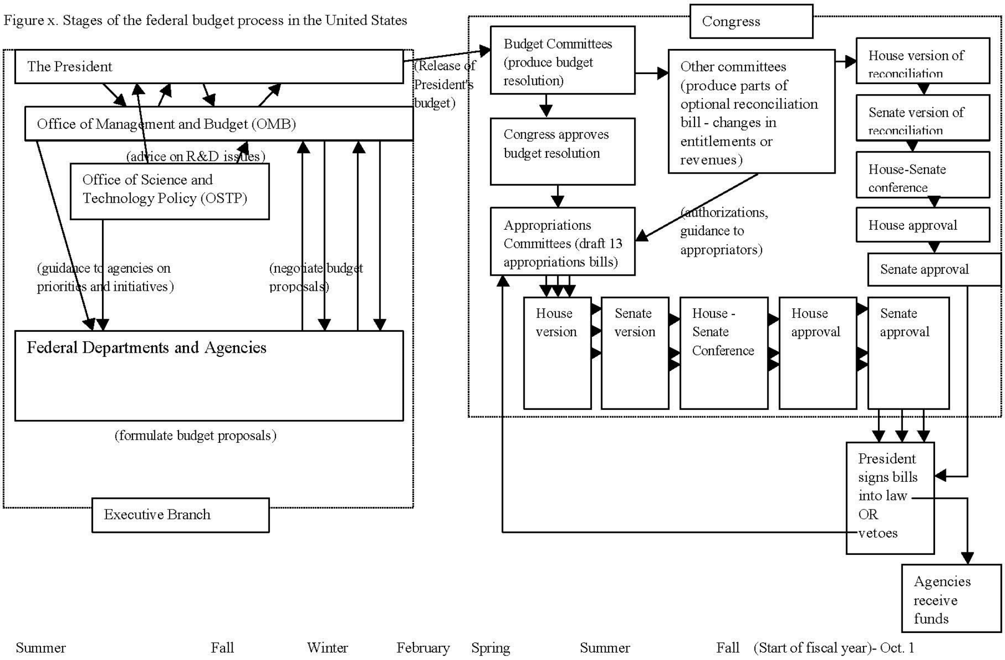
It must be emphasized again that there is no single overall science and research budget in the United States. Investment in research has to compete with other activities within agencies and departments. It is only the National Science Foundation and the National Institutes of Health which have research as their sole mission. In fact, the NSF also has a program on education and human resources which consumes about 12 percent of NSF’s budget. The United States realized early the importance of education for the success of research and science.

Research comes under the so-called discretionary part of the U.S. budget. This is much smaller than the mandatory portion, which includes social security, government funded healthcare (Medicare and Medicaid), and other entitlements. Research investment is therefore more likely to increase when the American economy goes well and the overall budget is increasing. However, there is always a budget ceiling set by the President.

Particularly important when describing the current system of priority-setting is that in Congress, research investment by different departments and agencies is dealt with by different authorization and appropriation (the most important) committees and their subcommittees. Until recently, for example, the budgets for the NSF and NASA had to compete not only with each other, but also with other policy areas such as veterans affairs, housing and urban development, environmental programs and some others. A major reorganization of the appropriations subcommittees in 2007 improved the situation somewhat, but the budgets for the NSF and NASA still compete for funds with the commerce and justice budgets. The NIH budget has to compete with other activities within the Department of Health and Human Services, with education programs, and also with labor programs. Consequently, there is no way to measure the need for research in one area over another, such as biology versus biomedicine, or physics against environmental research needs.

The complicated nature of the federal budget process can be seen from figure 5.

Figure 5. Stages of the federal budget process



Source: "Science, Technology, and the Federal Budget", Kei Koizumi, AAAS, September 23, 2008.

This is in contrast to several other countries where there is a separate budget for research even if the research in question comes under different departments or ministries. It is of course true that even in these countries, research investment will have to compete with other policy areas in the overall budgets. In Sweden, a Bill for Research is presented to Parliament every four years. This usually proposes increases in research for the following four-year period.

So, how can priorities be set when there is no single budget? First of all, there is a need to distinguish between priorities at different levels. It is quite clear that, in terms of the political level (Administration and Congress), investment in research goes hand-in-hand with the political agendas at different times which often reflect emerging social or societal issues and problems. For example, the launch of Sputnik by the Soviets triggered huge investment in space research, and investment in defense R&D rose rapidly during the Reagan Administration when the military threat from the Soviet Union was felt as severe. The societal problems of the 1970s led to increased funding for other areas: President Nixon launched the war on cancer when that disease grew rapidly in the 1970s and investment in cancer research at the NIH grew rapidly. Furthermore, in difficult economic times research which could contribute to economic competitiveness comes to the forefront, as can be seen from President Obama's stimulus bill.

Broad priorities at the political level are possible to make and are made in democratic societies. At agency or departmental level, priorities are much harder to make, because as will be argued later on in Section 7.2 and Section 8, there are few valid and reliable sources or background information for setting priorities between disciplines and between disciplinary research and interdisciplinary research.

The White House (OSTP) usually gives broad directives on priorities to the departments and agencies two years ahead of a specific fiscal year. During the spring of 2009, the OSTP was working on priorities for fiscal year 2011 (Interview). Although they will most certainly continue to be broad, some well-informed science policy people believe that priorities may become more detailed under the Obama Administration (Interviews) This is because recruitment to higher science policy posts within the Administration involves very high-ranking scientists and also that the current economic problems of the U.S. as well as the increased focus on global issues (energy, environment, etc.) will affect research priorities to a higher extent than before. This might also be true of defense R&D (Interview).

The National Science and Technology Council (NSTC), has a strategic function in setting the research agenda and coordinating federal policies and interagency programs in science and technology. It is chaired by the President and its membership is made up of the Vice President, Director of the OSTP and heads of government departments and independent agencies with significant science and technology responsibilities. The work takes place in committees and subcommittees.

The President's Council of Advisors on Science and Technology, PCAST, is an advisory group of leading scientists and engineers which advises the President and Vice President and formulates policy in many areas where the understanding of science, technology and innovation is key to strengthening the American economy and formulating policy that works for the American people. PCAST consists of 20 members from academia and industry.

The National Science Board is another presidentially appointed committee of advisors on science and technology that, while primarily charged with the oversight of the National Science Foundation, must also advise the President and Congress on national science priorities. Also important for advice on science and technology priorities at the national level are the National Academy of Sciences, and the advocacy components of professional scientific societies.

The United States is not a parliamentary democracy. Congress plays a much more important role in the U.S. than many parliaments do in other countries. Congress decides on most items and sub-items in the budget for departments and agencies. Most of the decisions by Congress stems from proposals by the Administration, which in turn come from the departments and agencies. Sometimes, Members of Congress put forward proposals which do not exist in the proposal by the Administration. These are called earmarks and serve as a means to foster development of the place or region represented by that Member of Congress. Earmarks affecting the NSF or the NIH are not very common (Interview). In the NSF budget, Members of Congress are more apt to “interfere” in educational issues than scientific ones.

There is also the issue of setting priorities between basic research, applied research and development. This is not really done in the U.S. because basic research can be financed by many departments and agencies, not just the NSF which has this as its sole objective. It could also be argued that the NIH has basic research as an important mission *within* its disease-oriented objectives.

As previously argued, this does not mean that basic research differs from basic research in other countries, or that it is ignored on the political agenda or in political rhetoric. In fact, the America COMPETES Act in 2007, where American industry took a leading role (Interview) stressed the need for *basic* research in physics. The argument can sometimes be heard that the reason for American competitiveness lies in the fact that the U.S. has no mission of science for science’s sake and that the NSF only holds a small part (around 4 percent) of the total R&D budget of the U.S. Government. However, there is no evidence supporting this view. The fact that there has been substantial investment in basic research by the Federal Government, mainly at U.S. universities, may be a reason for the strength of American competitiveness. Still, it is hard to know for sure.

The actual mechanisms for priority-setting in the U.S. are described as follows: Departments and Agencies put forward detailed budget proposals to the Administration, i.e. to the OSTP within the White House and to the Office of Management and Budget, OMB (this latter has the real power). Priority-setting is actually a work of compromise taking place over several months of negotiations between the senior leadership of various departments and agencies and the OMB. The OMB is thus heavily involved in deciding both which priorities make it into the final budget request and the level of funding.

Because it is a component of the larger Department of Health and Human Services (HHS), the NIH must first send its proposal for inclusion in the overall budget of the HHS. The HHS does not normally change anything in the proposal from the NIH (Interview).

The OSTP gives science and technology policy advice to the President on a number of issues, including the budget, and coordinates efforts of federal agencies and other actors. The head of the OSTP is the President’s Science Advisor. During the Bush

Administration 2000-2007 the Science Advisor was not a member of the Cabinet. Many view this as a sign that science did not play an important role in national policies during that Administration. There were also other issues, such as the rules governing stem cell research, which further strengthened this view. Others, no doubt fewer, counter that the steadily increasing R&D budget (beyond inflation) during most of the years of the Bush Administration is evidence of a high priority placed on science.

The OMB modifies the budget proposals received from departments and agencies to adjust them to the budget ceiling. For example, the NIH usually asks for increases of 8-10 percent. The OMB cuts this down to 3-5 percent to fit within the budget ceiling. However, the NIH, the OMB and the OSTP all know and expect that Congress, responding to the advocacy of strong medical research lobbyists, will increase the size considerably in relation to the proposals. Other agencies cannot always rely on a similar groundswell of public support to sustain their budget. Many discussions and negotiations will be held with the departments and agencies during the course of the deliberations in the OMB and OSTP. After a few months, the final budget proposal of the Administration is sent to Congress.

Early August 2009, the OMB and OSTP issued guidelines for departments and agencies (“Science and Technology Priorities for the FY 20011 Budget”). Their memorandum states that in their budget submissions, agencies should explain “how they will redirect available resources, as appropriate, from lower-priority areas to science and technology activities that address four practical challenges and strengthen four cross-cutting areas that underlie success in addressing all of them”. The four practical challenges are:

- Applying science and technology strategies to drive economic recovery, job creation and economic growth
- Promoting innovative energy technologies to reduce dependence on energy imports and mitigate the impact of climate-change while creating green jobs and new businesses
- Applying biomedical science and information technology to help Americans live longer, healthier lives while reducing healthcare costs
- Assuring we have the technologies needed to protect our troops, citizens, and national interests, including those needed to verify arms control and non-proliferation agreements essential to our security.

Addressing these challenges will require:

- Increasing the productivity of our research institutions, including our research universities and major public and private laboratories and research centers;

- Strengthening science, technology and engineering, and mathematics education at every level, from pre-college to post-graduate to lifelong learning;
- Improving and protecting our information, communication, and transportation infrastructure, which is essential to our commerce, science, and security alike; and
- Enhancing our capabilities in space, which are essential for communications, geopositioning, intelligence gathering, Earth observation, and national defense, as well as increasing our understanding of the universe and our place in it.

Agencies and departments are required to describe the expected outcomes from their research in relation to these four practical challenges and cross-cutting areas; to strengthen their capacity to evaluate programs; to show how assessments allowed agencies to eliminate or reduce funding for less-effective, lower-quality, lower-priority programs in 2011; to explain how they plan to take advantage of today's open innovation model in order to become more open to ideas from many players; how they will provide support for long-term, visionary thinkers proposing high-risk, high pay-off research; to develop outcome-oriented goals for their science and technology activities; to develop "science of science policy" tools; and to conduct programs in accordance with the highest standards of ethical and scientific integrity.

In Congress, the budget is discussed in both the House of Representatives and in the Senate. Authorization committees in both chambers, with their subcommittees (for example, the Subcommittee on Research and Science Education of the House Committee on Science and Technology authorizes the National Science Foundation's budget), deal with the content and choose whether or not to authorize the proposals from the White House. Authorization committees contain a lot of expertise in science-related phenomena. Members of these committees are helped by knowledgeable congressional research staff. The appropriation committees are the ones that actually decide whether to allow for the requested investment. The proposal to double the budget of the NSF which came up several years ago as a response to the doubling of the budget of the NIH which took place from 1998 to 2003, was authorized but not appropriated. Another reason for the wish to double the budget of the NSF was to create some "balance" between the investment in different disciplines.

During the deliberations in Congress, heads of departments and agencies are often called to hearings many times to focus on a specific issue or issues. The processes in Congress frequently take so long that the budget for the next fiscal year is not taken before that fiscal year starts. When this is the case, there is authorization from Congress to continue the spending level of departments and agencies at the level of the previous year.

Even so, the priorities set at the political level are not only a matter between the departments and agencies, the Administration and Congress. Other actors are involved in trying to influence decisions. Some actors give advice, others primarily lobby in Congress. Initiatives to invest in a specific research area may be strongly influenced by these actors, such as scientific organizations, industry, professional organizations, patient groups, etc. Washington, D.C. has thousands of lobbying organizations trying to influence congressional decisions, including those representing universities.

The National Academies have a clear role in science advice. The National Academy of Sciences was established in 1863 and was later joined by two other academies – the National Academy of Engineering in 1964 and the Institute of Medicine in 1970. These are non-profit organizations which provide a public service by working outside the framework of government to ensure independent advice on matters of science, technology and medicine. Through their operating arm, the National Research Council, they undertake studies for federal agencies and Congress but also start projects at their own initiative. The activities cover every scientific area as well as policy and innovation issues. Sometimes, they play a very important role in science advice, such as in the 2007 report “Rising above the Gathering Storm”, which laid the foundation for the America COMPETES Act. In other instances, their work may be recognized but less influential in the course of science policy.

Another important actor in science policy at federal level is the American Association for the Advancement of Science, AAAS. This is a non-profit organization with the mission to advance science and innovation throughout the world. It is important because of its large membership and different activities in science policy and education and the analyses it makes of the budget authorizations in Congress. The AAAS publishes the journal Science.

So much for the highest political level, but what about priority-setting within agencies? How much is top-down versus bottom-up in science priorities? How much are scientists and groups representing other interests involved in priority-setting? To answer such questions, it is necessary to move to departmental or agency level. It would have been ideal to look at priority-setting in several of the U.S. departments and agencies to get a more comprehensive picture, but that is beyond the scope of this report. Priority-setting at the NSF and the NIH will be covered below because these institutions have science as their main mission.

4.2 Priority-Setting at the NSF

The National Science Foundation (NSF) is an independent federal agency created by Congress in 1950 with the mission “to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…”. The NSF is the only federal agency whose mission includes support for all fields of fundamental science and engineering except for medical sciences. Its budget totaled USD 6.128 billion in the 2008 fiscal year, of which 79 percent went to research and related activities, and 12 percent to education and human resources. It is funded primarily through six congressional appropriations.

The NSF's share of total annual federal spending for R&D amounted to 4 percent, and its share of federal funding for non-medical basic research at academic institutions to 44 percent. In some fields, the NSF is the principal source of federal academic support. Most of the awards granted go to colleges, universities and academic consortia (73 percent), but resources are also granted for federal agencies and laboratories (9 percent) and the rest to non-profit organizations (7 percent) and for-profit businesses (6 percent).

The NSF has defined four strategic goals: Discovery (54 percent of the FY 2008 budget), Research infrastructure (26 percent), Learning (14 percent) and Stewardship (6 percent).

There are seven directorates and six offices at the NSF. Directorates include biological sciences, computer and information science and engineering, education and human resources, engineering, geosciences, mathematical and physical sciences, and social, behavioral and economic sciences. The offices are in cyberinfrastructure, integrative activities, international science and engineering, polar programs, budget, finance and award management and information and resource management. The Office of Integrative Activities promotes unity and alignment in support of the Foundation's mission, coordinating and overseeing cross-directorate activities and providing policy support to the Office of the Director (FY 2008 Highlights).

The NSF supports almost 200,000 researchers, postdoctoral fellows, trainees, teachers and students per year. In 2008 it evaluated almost 45,000 proposals through a competitive merit review process and funded more than 11,000 competitive awards.

Priority-setting at the NSF begins with the individual researcher who proposes research to the NSF. The core programs of the NSF are disciplinary programs to which researchers submit unsolicited proposals. Since these proposals are not solicited, the researchers themselves determine the direction of the research, and, in aggregate, new trends and priorities emerge. Consequently, most of the research funded by the NSF is bottom-up, i.e. influenced by the choices of the scientific community. One estimate is that around 85 percent of research funded by the NSF can be classified as bottom-up (Interview). In addition, some disciplinary areas are more bottom-up than others. This is true of, say, astronomy where there is a need to plan about ten years ahead because of the major infrastructure needed for astronomy research. There are few outsiders who could evaluate the technology needed or potential of the research. Also, for computational sciences and mathematics, intellectual merit is the sole criterion (Interview).

Even if most research supported by the NSF is bottom-up, decisions about funding is not purely based on peer review. This fact may not be well known in Europe. The NSF uses expert panels to evaluate proposals but decisions are based also on the potential broader impacts of the research proposal. This is why the NSF uses the term “merit review”. The broader impacts may include how the research can contribute to education, or reaching a specific societal goal, and how it will affect recruitment of minorities, etc. Particularly important is how the research can contribute to promote education and training as education is the best form of technology transfer (Interview).

The Program Officers at the NSF are responsible for making the final selection of proposals for funding. Most of the Program Officers are involved in multiple programs or solicitations to some degree, but will generally have a primary program responsibility. Program Officers will take into account how the research proposal fits into the overall priorities of the NSF. The Assistant Directors, i.e. the heads of each NSF Directorate, are entitled to change the decisions made by Program Officers but rarely do so (Interviews).

Other mechanisms that the NSF uses to gain advice straight from the individual researchers are meetings, workshops and seminars. All year long and in nearly every discipline and sub-discipline, workshops, meetings of funded investigators, and seminars on current topics of interest are sponsored by the NSF as a means to bring interested parties together to determine new directions and opportunities. The reports generated from these meetings serve as advice to the NSF in developing new targeted (solicited) opportunities for research, particularly in cross-disciplinary or emerging areas.

The NSF also has multiple advisory committees that serve to aggregate opinions and current findings from their communities and deliver formal advice to senior NSF management about priorities and opportunities. In fact, every Assistant Director at the NSF has an advisory committee at his/her disposal which usually meets twice a year. Some of these committees seem to be used more frequently, i.e. also between meetings to give the Assistant Director more advice from the “outside”. Advisors mostly come from academia but industry is also frequently involved. This is also true of the Directorate for Education and Human Resources. Some directorates have subcommittees to deal with specific issues, such as the Subcommittee for Large Facilities within the Directorate of Mathematical and Physical Sciences.

Every division within the different directorates has an audit every three years by external scientists, forming a committee of visitors, which evaluates both the relevant portfolio and the process. The committee of visitors is charged by the advisory committee.

The NSF's senior management, guided by the Director and Deputy Director, participate in numerous sessions during the course of the year to review advice from the community and talk about opportunities both within the disciplinary directorates and across the foundation. Twice a year they meet for a retreat, timed to fit the budget process. On these occasions, the overall priorities are discussed and how they fit into the activities of the different directorates. Opportunities for cross-disciplinary and inter-disciplinary research can also be identified. New initiatives, in particular, are the result of these senior management deliberations. The initial budget request to the OMB and OSTP is prepared by the Director based on these deliberations. The National Science Board, the presidentially appointed oversight body of the NSF, also guides and advises on priorities, consults on budget development, and must approve the NSF's budget request.

It should also be pointed out that however much policy at the NSF is influenced by the scientific community, senior management plays an important role in the direction of research and in taking initiatives. One former NSF Director, Erich Bloch, pushed for the creation of engineering research centers, and the NSF-wide initiatives often tend to mirror the priorities and/or scientific background of Directors or Assistant Directors.

The budget request is quite detailed, with separate funds for operations, infrastructure, support of research, running the science board, etc. These funds must be used for their appropriated purpose and cannot be switched from one category to the other by the NSF without going back to the OMB and Congress for approval. Within these broad categories, there is significant itemization and only very limited flexibility for the NSF. The research budget is detailed as totals for directorates, amounts for each division within the directorate, and often specific amounts for individual programs, especially new or high priority ones. There will also be detailed amounts specified for cross-directorate programs and new initiatives. For more information about the NSF budget see http://nsf.gov/about/budget/fy2010/pdf/entire_fy2010.pdf. Congress decides on the full, detailed budget, and often gets into the minutiae. Frequently, they will adjust sums for various programs or initiatives at the level of plus or minus hundreds of thousands of dollars in a total budget of USD 6.5 billion.

Programs receive their annual budgets from their division management shortly after the total NSF budget is appropriated. If theirs is a large or highly visible program, the budget may have been separately specified in the overall NSF budget request. However, in general, the division or directorate has flexibility to determine allocations between several related programs grouped together in the appropriation. These will be allocated based on the level of community interest, quality of proposals, how well the Program Officers advocate for their program, etc. However for funding levels specified in the appropriated budget (whether an individual program or aggregated over several), the NSF has only very limited flexibility to redirect funds. If the desired flexibility is for more than a nominal change from the original plan, the NSF would have to go back to the OMB and/or Congress for approval.

As stated earlier in the section entitled History of Priority-Setting, there is a strong belief in interdisciplinarity as a means to foster scientific progress and help solve societal problems. This belief triggered Congress to direct the National Science Board to evaluate the role of the NSF in supporting interdisciplinary research in relation to the America COMPETES Act in 2006. The Board tried to assess the extent of support for interdisciplinarity but pointed to the difficulty in doing so because there are no uniform guidelines for designating a research project as interdisciplinary, and proposals and awards are not designated as such in NSF databases. However, they highlighted the fact that almost half of NSF awards in 2007 had more than one principal investigator, eight percent of NSF research awards received funding from more than one division and are therefore likely to be interdisciplinary, and 35 percent of about 350 active funding opportunities listed on the NSF website on a single day in July 2008 contained the term "interdisciplinary". Together with other indicators, the Board concluded that the NSF is receptive to interdisciplinary research proposals and actively engaged in supporting interdisciplinary research. The Board recommended against defining a fixed portion of the NSF budget for funding such research (NSB, "Report to Congress on Interdisciplinary Research at the National Science Foundation", August 2008).

There are other concepts gaining ground in the science policy discussions in the United States. One is transformative research, the other is high-risk, high-return research. Often they are used in a synonymous way. The first term points to the need or wish that those research areas or projects could be identified which would result in major breakthroughs in scientific or societal terms, and therefore investments in them should be made. The second refers to the fact that if those research areas with high returns, or projects with high scientific or societal returns could be identified, then a lot of time, energy, and money could be saved. By definition, in high risk research the probability of returns is much lower than in "conventional" research. The question is how policymakers at different levels can identify what is transformative research, or high–risk, high-return research.

According to those interviewed at the NSF, there are great difficulties in applying these concepts. What scientist would not argue that his/her research is transformative? And what mechanisms are there to judge whether a research project is high-risk, high-return?

The National Science Board (Board) established the Task Force on Transformative Research (Task Force) in December 2004 to serve as a Board focal point for gaining a better understanding of National Science Foundation (NSF) policies to solicit, identify, and fund innovative, "potentially transformative" research. Transformative research is defined as research driven by ideas that have the potential to radically change our understanding of an important existing scientific or engineering concept or leading to the creation of a new paradigm or field of science or engineering. Such research is also characterized by its challenge to current understanding or its pathway to new frontiers (NSB, “Enhancing the Support of Transformative Research at the National Science Foundation”, May 2007).

This report and the increasing pressure put on all government agencies and departments through the GPRA and PART led the NSF to launch a program emphasizing high-risk, high-return or “transformative” research. The NSF also continues to work with its proposer community and government program evaluators to develop evaluation methodologies and metrics that ensure accountability over the use of public funds and yet are appropriate for the uncertain, long-term research environment.

4.3 Priority-Setting at the National Institutes of Health

The mission of the NIH is to uncover new knowledge that will lead to better health for everyone. To meet its mission, the NIH supports both disease-specific research and basic research. The NIH works toward that mission by conducting research in its own laboratories (intramural research), by supporting the research of non-federal scientists in universities, medical schools, hospitals, and research institutions abroad (extramural research). It also assists in the training of investigators and in fostering communication of medical information. Like many other federal agencies, the NIH is engaged in technology transfer activities. Support for research on one disease is not limited to one institute but is often carried out by different institutes at the same time. Disease-oriented institutes also support basic research. Research results from NIH-funded projects are often relevant to more than one disease. (“American Science – the Envy of the World”, ITPS, Stockholm 2004)

The NIH is the largest single funder of biomedical research in the world. In 2007, the NIH invested USD 28 billion in medical research after the doubling of the NIH budget between 1997 and 2004. More than 83 percent of the NIH’s funding is awarded through almost 50,000 competitive grants to more than 325,000 researchers at over 3,000 universities, medical schools and other research institutions in every state and around the world. About 10 percent of the NIH’s budget supports projects conducted by nearly 6,000 scientists in its own laboratories, most of which are on the NIH campus in Bethesda, Maryland, outside of Washington, D.C. (NIH webpage).

The 20 institutes and seven centers (ICs) within the NIH are quite diverse in their mission and scope of activity and size, but are similar in the way they are organized and the way they support researchers. The institutes are differently categorized. Several are disease-oriented, such as the National Cancer Institute (NCI). Some refer to a specific organ of the body, such as the National Heart, Lung and Blood Institute (NHLBI). Other institutes are geared towards a specific life stage, such as the Institute on Aging (NIA), and a few others are categorized by field of science or by profession or technology. Every institute and four centers award research grants, mostly to scientists at universities and non-federal research institutions (ITPS 2004).

There is also the Office of the Director (OD) of the NIH which provides leadership, oversight, and coordination for the entire NIH research enterprise. Within the OD there is a new structure, mandated by the NIH Reform Act of 2006, for program coordination, planning and strategic initiatives. There are also four program offices for disease prevention, behavioral and social sciences research, women's health and Aids research. Within the Director's offices, there is NIH-wide oversight and coordination in science policy and science education, biotechnology, legislation, communications, ethics, and in most other areas requesting coordination in the multitude of institutes and activities that the NIH is involved in.

The main part of the extramural funding is distributed to investigator-initiated applications from individual scientists. These are the Research Projects Grants (RPGs), which are awarded across a spectrum, from cellular and molecular research to finding new drugs to treat human illness. The most common within this category is known as the R01. The R01 supports a single project and a single investigator. Some project grants are given to multi-disciplinary projects conducted by several researchers and with different focuses on the research problem; these are called Program Project Grants. Multi-disciplinary projects and collaborating researchers are also supported by research center grants. These grants are awarded to research institutions. For example, the NCI has large centers in clinical and basic research, e.g. at Columbia Medical School and the University of North Carolina. Another supporter of research centers is the National Center for Research Resources (NCRR). Grants also support the development of research resources to integrate basic research with applied research and to promote research in clinical applications. (ITPS 2004)

All applications in the *extramural programs* are sent to the NIH and the Center for Scientific Review (CSR). CSR distributes them to the different institutes. The final decision on whether an application is to be funded is made by the institutes. Before such a decision is made, the grant proposal has to go through several steps, a process which is standardized across the NIH institutes. These include rating criteria, policies and procedures in the conduct of review meetings and the use of standardized committees and special emphasis panels.

The CSR's Division of Receipt and Referral receives all grant applications. The Scientific Review Administrators (SRA) make the first important decision, which is to classify the proposal, assign it to an appropriate peer review group (Integrated Review Group) for scientific review and to an appropriate institute or center for funding. Sometimes the application is multidisciplinary and is therefore submitted to more than one institute. The more than one hundred study sections at the NIH meet approximately three times a year and are not open to the public. To manage the workload at the CSR and at the institutes, the reviews are made in three cycles each year and carried out in two steps.

Each application goes through a peer review process by the CSR to assess the scientific merit of the application. This is the first step. The study sections consist of 15–20 scientific experts, mostly researchers within the biomedical sciences. The SRAs nominate the members and in this process they look for diversity in gender, race, geography, etc. Temporary members are frequently brought into the study sections. The status and prestige that derive from being an NIH reviewer is the main reason for joining a study section, but also the chance to get insights into and learn about the review process.

The research proposal is reviewed according to the following scientific and technical merit criteria: Significance of the problem; appropriateness of the concepts and methods; innovation in terms of novel concepts in approaching the problem and; training of investigators and the scientific environment in which the work will be done. Each application is normally assigned to two or more members of the study section for detailed written review comments. Other members are designed as readers and the application is ranked with a numeric score. This score reflects the potential impact of the project in terms of the five criteria mentioned above (significance, approach, innovation, investigator, and environment), and is arrived at through discussions and votes by all members of the group.

National advisory councils or boards at the institutes, including both scientists and public members interested in health issues and/or the biomedical sciences, carry out the second step. Identifying applications that promote specific program priorities is a particularly important function of this second level of peer review. These councils also meet about three or four times per year. Each institute has its own advisory council, mandated by Congress. A council can never reverse the decisions of a study section, but it can recommend funding of applications that have not received the highest scores but which still seem very important.

Only applications that are scientifically meritorious, based on SRC review, and favorably recommended by national advisory councils may be considered for funding. The priority score given to an application during the peer review process is important, but not the sole factor determining an institute’s or center’s funding decision. Other considerations are programmatic relevance, priorities of the institute or centre, contribution to balance in light of existing IC research portfolio, and amount of the award (NIH Biennial Report of the Director, FY 06-07).

The NIH *Intramural Research Program* conducts basic, translational, and clinical research. Most ICs have an intramural program. The NIH Office of Intramural

Research is responsible for trans-NIH oversight and coordination of intramural research. As with the extramural program, intramural research proposals are generated by scientists. In the intramural research program, however, program directions and priorities are not generally shaped through grant awards but rather through professional hiring and promotion decisions, external reviews, and the allocation of resources to laboratories and branches (NIH Biennial Report).

Strategic planning and priority-setting at the NIH is a highly consultative process involving many constituencies that generate and provide input on public health needs and research gaps, opportunities and priorities. Strategic planning takes place at many levels. Most important, the U.S. Congress, through the NIH authorization and appropriations processes, sets IC funding levels, establishes the missions for some ICs and directs the NIH's attention to particular areas of research interest or emphasis. The Administration also establishes priorities for improving the health of the Nation that must be addressed by the NIH. An example is *Healthy People 2010,* a comprehensive set of disease prevention and health promotion objectives for the nation to achieve by 2010. (NIH Biennial Report).

The NIH Roadmap was launched by the former Director of the NIH, Dr. Elias Zerhouni, and is a strategic plan for the whole agency. The process to identify and prioritize the most pressing problems facing medical research areas started in 2002 with consultations with a broad range of stakeholders. The ideas that emerged were evaluated according to: whether the initiative had a high potential to transform the way health research is conducted; how it would synergize with but cut across the individual missions of the ICs, ensuring that it would not be redundant with activities conducted by other agencies or entities; and whether it was expected to have an impact of public health such that results could be broadly disseminated and in the public domain. Thirty initiatives were launched under three broad themes in 2003.

Roadmap initiatives are a collective NIH-wide resource supported through the NIH Common Fund. They were previously funded through contributions from the ICs and the Office of the Director, but since FY 2007 they have been funded solely within the OD appropriation level. Initiatives either transition out to the ICs after a five or ten year period or are concluded.

The Common Fund amounts to about 1.7 percent of the total NIH budget. Congress grants money for this fund separately. The Common Fund can be compared to a venture capital fund. It is a high-risk, high-impact fund. Investment might fail. (Interview).

To select and plan the next generation of Roadmap initiatives the NIH solicited ideas from the intramural and extramural scientific community, patient advocates and the general public during the summer and fall 2006. After comprehensive reviews of the submissions, and broad consultations within the NIH, two new topics were identified: Microbiome and Epigenetics.

The majority of strategic planning at the NIH is thus based within the different ICs, even though there may be cross-disciplinary activities funded by separate ICs. Each NIH IC has unique processes for developing and disseminating its strategic plans. These plans naturally influence the IC decisions on which applications to fund. Many of the ICs also have disease and program-specific strategic plans and research agendas.

To summarize: Strategic planning and priority-setting at the NIH is a very complex process involving a number of different actors. Priority areas are decided after getting advice from special committees, workshops and conferences, solicitations, etc. Consultations take place with individual researchers, research teams and academic communities, patient organizations, advisory groups within the ICs, the Advisory Committee to the Director, and the personnel within the NIH. As was pointed out earlier, the Administration and particularly Congress have a major influence on priority-setting, perhaps more so than parliaments in other countries. What is also unique about the U.S. is the heavy influence of patient groups in the priority-setting processes. However, what projects get funding is basically a bottom-up process.

Both the NSF and NIH rely heavily on a bottom-up approach, getting ideas and advice from workshops, studies by the National Academies, unsolicited ideas from the proposer community etc. to determine new trends and new opportunities. Also, both have community advisory groups to help with setting new directions. One difference is that the NSF has a board which is also a direct advisor to the OSTP, while the NIH does not. However, the biggest difference between the two might be that the NIH has a very well-organized advocacy community. Essentially every NIH institute or major program has a corresponding “disease advocacy group” which lobby Congress and influence public opinion to invest more resources in medical research. These groups are well organized, well funded, and highly influential.

Often the investment of resources more closely correlates with the size and influence of the advocacy group than it does with the actual incidence of or cost to society of the disease. For example, as Newsweek reported some time ago: “public and private funding for [epilepsy] research lags far behind other neurological afflictions, at USD 35 a patient (compared, for instance, with USD 129 for Alzheimer’s and USD 280 for multiple sclerosis). It is time to remedy that gap, and raise epilepsy to the front ranks of public and medical concern” (Newsweek, April 11, 2009). It seems as if the advocacy for epilepsy research is not as organized and well funded as for other major diseases.

5 Issues in Priority-Setting

There are of course some general concerns in the science policy debate which affect the issue of priority-setting in the United States. The concern about a well educated and trained workforce for the future high-technology economy is one of them. Also, the process of innovation—understanding how it occurs, how to promote it, and how to train to increase innovative capacity—is another. And making the transition for research results into practical use and into the market more efficiently and timely is high on the political agenda. All these issues motivate much of the thinking across disciplines and in terms of guiding Administration-wide broad initiatives. These issues were very much stressed in the America COMPETES Act.

There are three questions that R&D administrators at the top levels are asking themselves in terms of how to set the science agency budgets:

- How to know what is the right level of spending on R&D in the context of the Federal Discretionary Budget? As noted, the Federal Discretionary Budget is finite and trends with the state of the economy. In the appropriations process, R&D competes directly with other spending priorities; there is no pre-determined formula or percentage. Public opinion does not provide much help, as is also true in many other countries. Although 34 percent think the government spends too little on scientific research, compared to only 13 percent who believe it is too much (NSF Science and Technology Indicators, 2008), public opinion also heavily supports increased funding on reducing pollution, improving healthcare, improving education, and assistance to the poor – all areas which compete with scientific research for the discretionary budget. However, public opinion in the United States does not correspondingly approve increased taxes to allow such increased spending to occur.
- How to apportion spending to the many different scientific disciplines? This is a very difficult and delicate issue. While groups have successfully tackled priorities within disciplines (e.g. the National Academies decadal plan for physics and astronomy identified “grand challenges” to guide the prioritization of funding within these disciplines), few have wanted to tackle prioritization of physics -v- biology -v- social science or geosciences. Yet apportionment of funding must occur, whether or not there is a coherent sense of priorities to guide the process. In the late 1990s, public opinion on the importance of medical research resulted in a plan to double research funding for the NIH. With relatively modest increases in other fields over the same time, some science leaders, including former Presidential Science Advisor John Marburger, believed that funding levels had

gotten out of balance. They argued for similar increases in physics, mathematics, computer science and engineering that would maintain the beneficial free flow of ideas and cross-disciplinary progress that occurs best when all fields advance simultaneously.

- How to evaluate agencies, programs and projects for accountability and performance without perturbing the system in unforeseen and potentially negative ways? The United States is under great pressure to demonstrate responsible use of public funds and advertises a "results-oriented" government. All federal agencies fall under the requirements of the Government Performance and Results Act of 1993 and, at least during the Bush Administration, the Performance Assessment Rating Tool. Both require the detailing of the results and immediate benefits of all government spending, with emphasis of concrete and quantitative performance measures. While good-faith efforts on all sides have been made to adapt these requirements to basic research programs in the federal research agencies, they continue to struggle to find meaningful measures that do not also induce excessive conservatism into the research selection process. As a response, both the NSF and NIH have developed new programs that emphasize high-risk, high-reward or "transformative" research, and continue to work with both their proposer community and government program evaluators to develop evaluation methodologies and metrics that ensure accountability over the use of public funds but which at the same time are appropriate for the uncertain and long-term research environment.

The U.S. has historically and will likely continue to rely primarily on the expert judgment of the administrators and advisors chosen by the Administration to decide the above priority questions. However, in recent years, much more emphasis has been given to the potential of indicators and theoretical analysis of the national and global research and innovation systems to provide insights useful to the process. As was pointed out earlier, John Marburger challenged the social science community early in the Administration to develop the nascent field of the "science of science policy." In a speech to the AAAS Science Policy Forum in 2005, he further explained: "I am suggesting that the nascent field of the social science of science policy needs to grow up, and quickly, to provide a basis for understanding the enormously complex dynamic of today's global, technology-based society." Having identified this area of research as a branch of economics, Dr. Marburger then made a strong plea for the development of "econometric" models to assist in the policy process.

Several of the federal research agencies have since initiated programs, such as the NSF's Science of Science and Innovation Policy, to begin to develop these capabilities. It is hoped that new indicators and models will help elucidate the complex systems and interdependencies and that this will give the experts valuable information to help inform their judgments, which will still be the primary mechanism for making decisions and trade-offs in policy development.

6 Characteristics of the U.S. Science System, Policymaking and Priority-Setting

As is clear from the above, there has been a constant debate in the U.S. about the need for a comprehensive science policy, a science budget, longer term planning, valid and reliable information for setting priorities, etc. Many Americans see the science system in the U.S. as chaotic, uncoordinated, characterized by “letting a thousand flowers bloom” and an issue which cannot be solved. Some see it as a futile endeavor which does not need to be solved.

It is indeed a very large system and highly pluralistic. Many actors are involved in giving views on priorities and advice in general. Some argue that the mission-oriented perspective, which is really prevalent in the American system, is the key to the success of U.S. science. When such a perspective is prevalent, there is a lesser need to argue about the importance of basic versus applied research. Departments and agencies in the U.S. often have several missions and are engaged in financing both basic and applied research as well as development. As has been shown earlier in this report many are also engaged in financing several disciplines. The NSF can be regarded as an exception to the rule as it basically has one mission in science: to foster the development of basic science.

The bottom-up approach is clearly very strong both at the NSF and NIH. Unsolicited proposals, workshops and seminars, advisory groups etc. give scientists ample opportunities to influence the direction of research and priority-setting. At the same time, decisions on proposals and directions are not solely based on peer review. Other factors also come into play, such as how proposals could contribute to education and training, address issues of societal relevance, cater to the needs and the potential of minority groups, meeting the needs of research infrastructure, and fit into the overall priorities of the agency or the department. This multi-purpose characteristic of research funding does not seem to be questioned very much in the U.S. whereas the advantages of this combination of funding based on excellence *and* other factors may be more debatable in other countries.

Directives on priorities given by the Administration to departments and agencies seem to be made in very broad terms, i.e. not very detailed with specific sums devoted to singular research areas. What actually comes out as priorities at the federal level largely build on the priorities put forward by the departments and agencies. However, as has been pointed out earlier, the different items in the budget have been negotiated between the OSTP, the OMB and partly Congress and once the budget items are fixed there is little leeway for departments and agencies to change them.

The mission-oriented perspective may also foster interdisciplinarity. The NSF is clearly engaged in interdisciplinarity but other departments and agencies are also involved. However, whether scientists in the U.S. are working more across disciplines than their European counterparts is hard to say.

Another fact often referred to when it comes to the success of American science and competitiveness is the concentration of federal research resources to the top American research universities. The top 100 research universities receive approximately 80 percent of federal funds. However, there are programs within the NSF that particularly take geographic considerations into account and where there is an explicit motivation to help less scientifically advanced regions to develop their research.

The American society has a mobile population, not only geographically but also in terms of working in different sectors, whether in private business, government or academia.

The mobility of people contributes to an understanding of the roles and responsibilities that different actors have in the science system. One example worth mentioning when comparing the United States with Europe is that part of the workforce at the National Science Foundation works there for only a few years and then returns to academic work at a university or college.

Working together is also apparent when it comes to having representatives from business and industry in important advisory functions at the federal level. The latter are represented in PCAST, on the Board of the National Science Board, overseeing the NSF, and on the Council on Competitiveness – an independent and influential actor when it comes to analyzing U.S. competitiveness. As has been pointed out earlier in this report, industry is also included in different advisory groups to the federal departments and agencies. What is also typical of the American science system is that federal funds from departments and agencies are directed not only to the federal research institutes and universities but also to industry. Even the NSF supports industry, mainly through the Small Business and Innovation Research (SBIR) program, which requires federal departments and agencies to set aside a percentage of their research resources for the development of R&D in small businesses.

The pluralism in the financing of research might be an important factor in the success of the American research enterprise and economy. The Federal Government is large, so the possibilities of getting funds are multiple at federal level. However, there are also the States, which are becoming increasingly engaged in research, particularly in research for innovation. In addition, there are also the private and non-profit organizations which finance quite a lot of research at universities. Also, industry is a small but important partner of universities in R&D and in technology transfer.

The fact that quite a substantial part of university research is made possible through private endowments, (more so than funding from industry, which has lingered at around five percent of total university research), could be another explanatory factor in the success of American science. Both private and public universities are engaged in development, as fundraising and capability expansion are termed. This makes it possible for American universities to recruit the best scientists in the world and refrain from federal funding if they think that there are too many strings attached to that funding. During the Reagan Administration, there were universities—Harvard for example—that partly refrained from federal funding because of this.

There are two other characteristics of the American system which may be worth mentioning. One is the openness of the American system and the other is the strong desire to be the very best in every field of science.

Not only in hearings in Congress with representatives from the science world, but also in the open protocols from meetings in Congress, at various departments and agencies (and at least at the NSF), there is *open justification for not funding* specific applications. There is also a constant ongoing and open debate about the difficult issues in priority-setting. It is not an overstatement to say that in the U.S., anyone can, as a representative of an institution or organization or even as an individual, make an appointment with the OSTP, or an agency, or an elected leader to discuss their views of S&T priorities. The U.S. culture encourages such citizen involvement in government, and many do take the opportunity.

In my 2004 report from the United States to the Ministry of Education and Research in Sweden, and also in interviews about what makes the U.S. system so competitive, I have highlighted one specific factor which I believe to be of great importance for the success of science and innovation. The United States wants to be the best in science, innovation and competitiveness. There are constant comparisons with other countries, constant worries about losing ground. American universities are also heavily involved in comparing themselves to similar universities in the U.S. and in how they are doing academically as well as in other areas.

Finally, it is my view that there is a strong belief in the United States that science and research can contribute to solving societal issues and problems, such as economic difficulties, even in the short term. The massive resources from the stimulus package during the present Administration to the NSF and NIH is a sign of this (Interview).

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VINNOVA´s mission is to promote sustainable growth
by funding needs-driven research
and developing effective innovation systems

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