

## **STEERING AND FUNDING OF RESEARCH INSTITUTIONS COUNTRY REPORT: UNITED STATES**

### **Introduction**

This report on the research system of the United States draws on the US response to the project questionnaire, and on data gathered during a visit to US institutions and agencies in Washington DC, Pennsylvania, and California in March 2002. The visit was organised with the advice and assistance of the National Science Foundation.<sup>1</sup>

The US illustrates a category of national science systems which: have no single ministry dominant with respect to research; have higher education as the predominant public research performer, although the bulk of R&D is in industry; and has an intermediate research funding level, in the sense of organisations which are funded to fund others, rather than themselves being essentially research performers.

This paper has three main sections: a discussion of goals of the US research system, an overview of the publicly funded organisations within the US research system, and a review of selected current research policies and practices.

### **Goals of the US research system**

The US does not have a single national research plan, nor explicitly stated national research goals. Periodic statements, for example by the President and the Congress, certainly provide a sense of national purpose and direction for this very large, complex, pluralistic system. Goals are also either explicit or implicit in major budget allocations. Goals also inform the actions of a range of actors. There are multiple goals and priorities, emanating from different sources. Each administration has its own priorities for research (as expressed in the President's Science and Technology policy agenda), achieving these is through a complex and negotiated process involving the committee system of the US Congress, and changes can be and are made at many points. The White House Office of Science and Technology Policy, in its secretariat role for the National Science and Technology Council, has important policy co-ordination responsibilities. While there is neither a tightly integrated set of goals or anything like a unified national system for delivering them, overriding purposes can be detected with a broad consensus on many matters of national interest which help determine research priorities.

The President's 2003 budget request included the highest component for research and development to date (USD 111.8 billion, including a 9% increase in funding for basic research across agencies). The 'Federal Science and Technology' budget (FS&T) (a category recently identified separately from federal R&D to better highlight activities central to the creation of new knowledge and technologies), for which USD 57 billion has been requested for FY 2003 (9% increase), identifies several priorities.

---

1. Details of the schedule of visits and meetings are given in the Annexe. Questionnaire responses in Schindel (2001).

The most significant development among the various individual agencies is in the very broadly defined field of health. Over the past five years the annual budget of the National Institute of Health, for biomedical and research training, has doubled. This is an example of how goals and priorities emerge, not through a unified national process but through the sectoral mobilisation of resources. For 2003, the budget request stands at USD 27.3 billion (up from USD 13.6 billion in 1998).

Although representing only a small amount in overall research funding terms, OSTP seeks to foster multi-agency activities, choosing four priorities areas:

- Anti-terrorism (OMB, OSTP and the new Department of Homeland Security to work through NSTC to develop a co-ordinated, interagency R&D plan).
- Networking and Information Technology Research and Development Program (NITRD), co-ordinated by NSF (USD 1.9 billion, a 3% increase).
- National Nanotechnology Initiative, co-ordinated by NSF (USD 679 million, 17% increase).
- Climate change, including the Climate Change Research Initiative (USD 40 million) and the National Climate Change Technology Initiative (USD 40 million), complementing longstanding work under the US Global Change Research Program (USD 1.7 billion, a 3% increase).

Other priorities include a focus on merit based research funding, flagging the budget transfer of some R&D programs between agencies, towards those where more competitive, peer review award processes are seen as able to improve the scientific rigour of the programs. This priority seeks to discourage budget earmarking.

President's Management Agenda, a government-wide initiative to improve government performance, affects the research field in a number of ways. Notable is the effort of OMB to introduce clearly articulated criteria into the science evaluation process. Resources tend to flow to areas where performance targeting is progressing thus helping to establish a substantive priority. The government seeks to stimulate private investment in research through tax preferences, currently offering a 20% tax credit for private research and experimentation expenditures above a certain base amount. Priorities and goals are influenced by the uptake of these credits.

For a number of years the US has had as a priority encouraging the usage and development of federally funded research, as illustrated in the 1980 Bayh-Dole Act which enables researchers to retain the patent for research which was funded federally. The quest for patents and for intellectual property rights generally is another factor in goal setting.

In addition to statements on goals and priorities from government and quasi-government sources, the various national, autonomous scientific bodies and professional associations both state their own research priorities and contribute to shaping the national agenda. The overall process is thus not only complex, it provides many avenues for a wide variety of stakeholders to contribute to what is often a very transparent dialogue about goals formation and priority setting.

## **Overview of publicly funded organisations within the US research system**

The United States has a huge, dispersed and complex R&D system. In scale it dwarfs the systems of all other OECD countries: US gross domestic expenditure on R&D (GERD) equalled 43% of the total GERD

for all other OECD countries combined for 1998 (OECD, 2000, p.230). This massive R&D spending is dominantly in industry, although the considerable public investment in research plays a strategic role, notably in supporting basic research and research in fields not high in commercial interest. Scale alone sets the US apart (even if per capita figures bring the US closer to other countries), and is a major factor in explaining the dominant role the US came to play throughout the twentieth century in so many fields of research endeavour.

### *An evolving structure*

The major structures of the federal research portfolio date from the immediate post World War II period, and form part of the policy stimulated by Vannevar Bush to promote new scientific knowledge and develop scientific talent amongst youth. The experience of weapons development during the war years had highlighted the significant potential contribution of scientific research to national needs, and academic research was seen as a powerful means of achieving these results. Whereas before the War government funding for research was largely limited to government missions undertaken by federal employees in federal laboratories, post War funding privileged higher education institutions, and took a much broader focus, which continues to this day. A further fillip was given to research in the late 50s in the wake of Sputnik, with the US perception of having lost the scientific lead to the (then) Soviet Union. The military budget for research remained high until the effective end of the Cold War, with a notable boost during the Reagan Star Wars years. During the 1990s, civilian research emerged more prominently, and has remained so until very recently, with a mixed public-private economy of resourcing and delivery. Over some 50 years, the US has had a continuing, large federal research budget, which has fostered the development of an important stratum of research intensive universities, both public and private.

### *Diversity*

The US research system has an in-built set of checks and balances in keeping with the style of the country's constitution and governance. There is distributed power in the US system, contested at different levels along the way, exemplified in research decision making, as in other areas. The federal research system has remained relatively stable over a period of years and no major structural changes are presently envisioned. The research system maintains diversity which is seen as a strength in maintaining the risk taking behaviour which has, by common consent, served the US system well in its effective performance in science and technology.

### *Higher education*

While industry performs the largest proportion of R&D within the country, higher education institutions are the dominant **publicly** funded research performers. While public universities are, with minor exceptions, state level institutions in receipt of state funding based largely on student numbers, the bulk of research funding is, and has for long been, from federal sources. The considerable number of research intensive private universities also receive important research funding from federal agencies. State governments tend not to provide substantial research funding, although this appears to be changing, as discussed further below. Considerable variation exists between states in how university governance systems are designed and a recent study shows how different within-state structures (federal, unitary,

confederated systems, and confederated institutions) affect performance as well as strategies available to state policy makers (Bowen et al, 1997).<sup>2</sup>

The US has a diverse higher education system of some 3 000 institutions, including, in terms of the 2000 Carnegie Classification: doctoral/ research universities (6.6%), master's colleges and universities (15.5%), baccalaureate colleges (15.4%), associate's colleges (42.3%), specialized institutions (19.4%) and tribal colleges and universities (0.7%).<sup>3</sup> The bulk of research is undertaken in the doctoral/ research universities which comprise 261 institutions offering a wide range of baccalaureate programs, and committed to graduate education through the doctorate. Of these, 166 are public, 93 private not-for-profit, and two private, for-profit. Certain specialized institutions (such as medical schools and medical centres) may also undertake significant research. Although only a small proportion of higher education institutions are research intensive, because of the scale of the country, a significant number of institutions in numerical terms is involved.

A defining feature of the American research universities is the graduate school, which emerged under the direct influence of German academic science and scholarship during the late 19<sup>th</sup> and early 20<sup>th</sup> centuries. The graduate school is a university-wide administration for master's and doctoral degrees and faculty research and scholarship. It was built essentially as a new layer on top of the small freestanding (four-year undergraduate) colleges which had been characteristic of the US higher education to that point. The contemporary American research university typically has a single faculty or staff operating at both undergraduate and graduate levels, and divided into departments and faculties. Various independent research centres and institutes tend to be located within this structure, and university faculty commonly participate as members of research teams. American bachelors degrees tend to be broad-based and generalist and are offered by a considerable range of higher education institutions. The research masters and doctorates are offered by the research universities.

Of research and development undertaken in colleges and universities, totalling just over USD 30 billion in 2000, 58.2% was funded by the federal government, 7.3% by state and local government, 7.2% by industry, and 19.7% from institutional funds. Of this, 69.2% was classified as basic research, with 30.8% applied research and development. Some 58.1% of R&D was in the life sciences, followed by 15.1% in engineering, and 9% in the physical sciences (NSF, 2001).

### ***Government research institutions***

While performing less overall research than the higher education system, a variety of government controlled institutions still performs quite substantial amounts of research, in absolute terms. Apart from the National Science Foundation (NSF) which has no research institutions of its own, most federal research funding agencies have some intramural capacity. For the National Institutes of Health (NIH), this stands at around 10–11% of its funding, sufficient to maintain a significant research capability, including certain types of research which are deemed preferable to keep in-house (*e.g.* clinical research, short term/ urgent missions). Several federal departments (including defence, energy, health, veteran's affairs) have networks

---

2. System design and governance structures determine the range of strategies available to elected officials in their relationships with higher education institutions, as well as the likelihood that the officials will use such strategies. Some leadership styles seem to work better within some types of structures, and some structures (unitary systems in particular) are affected more extensively by changes in leadership than other structures (Bowen et al, 1997).

3. For definitions of categories, see [www.carnegiefoundation.org/Classification/CIHE2000/defNotes/Definitions.htm](http://www.carnegiefoundation.org/Classification/CIHE2000/defNotes/Definitions.htm)

of laboratories, which may individually be structured as Federally Funded R&D Centers (FFRDCs), and contracted to such outside bodies as a university or private sector company.<sup>4</sup> Some are classified, and tightly mission focused (*e.g.* Los Alamos), others unclassified and may engage in a broad range of research activities (*e.g.* Lawrence Berkeley Laboratory). The scale of research projects at these laboratories may be larger than those commonly undertaken through university departments and centres; also 27 large user facilities are based at Department of Energy laboratories. Other forms of public research institutions include government corporations structured as partnerships between the federal government and private industry; mission-oriented labs, and public hospitals doing clinical research. In addition, there are private non-profit laboratories which rely on federal research funds. Overall, then, government institutions are an important force in the overall research environment, contributing in a wide variety of ways to the national research endeavour.

### ***Federal government agencies and instrumentalities***

At the level of the federal government, some 30 agencies have research budgets. Those with the most significant research budgets (in terms of the Federal Science & Technology (FS&T) budget listing) proposed for FY2003, are:

- The **National Institutes of Health (NIH)**, with a USD 27.3 billion proposed budget for FY2003, represents a doubling since 1998. NIH, which comprises some 25 Institutes and Centers each focusing on particular health areas, funds biomedical research both intramurally, and through a peer-reviewed extramural program supporting some 50 000 scientists in 2 000 institutions nation-wide.
- **National Aeronautics and Space Administration (NASA)**, with USD 8.8 billion proposed for FY 2003, an 8% increase over 2002, funds research in three major fields: space science; earth science; biological/ physical research.
- The **National Science Foundation (NSF)**, with a broad-based mission to promote and advance progress in science and engineering in the US, funds programs across the spectrum of research, and supports science and research education at all levels. It has no laboratories of its own. With a proposed FY 2003 budget of USD 5.0 billion, a 5% increase, NSF provides about one quarter of federal funds for basic research in higher education.
- The **Department of Energy (DOE)**, with a proposed FY2003 FS&T budget of USD 5.0 billion, includes USD 3.3 billion for its Science programs (an increase of 1.5%), which provides key support for the physical sciences. DOE programs focus on energy, national nuclear security and environmental quality.
- The **Department of Defense (DOD)**, with a proposed FS&T budget for FY2003 of USD 5 billion, following September 11, 2001, has additional funds for research and development of technologies and systems addressing terrorist threats.
- **Other agencies with significant proposed FS&T budgets** for FY2003 are: Department of Agriculture (USD 1.9 billion, 1% increase); Department of the Interior (USD 904 million); Department of Commerce (USD 861 million); Environmental Protection Agency (USD 797 million); Department of Transportation (USD 548 million); Department of Education (USD 431 million); Department of Veterans Affairs (USD 409 million).

---

4. For an annotated list of FFRDCs, see [www.nsf.gov/sbe/srs/nsf02317/decert.htm](http://www.nsf.gov/sbe/srs/nsf02317/decert.htm)

The **executive branch of government** has four offices or councils which advise the President on research:

- **Office of Science and Technology Policy (OSTP)** helps co-ordinate federal science activities to meet presidential goals. Jointly with OMB, it issues an annual budget memorandum on research and development priorities. It also provides the secretariat for the NSTC. The Director of OSTP is the Assistant to the President for Science and Technology, thus the chief national adviser on S&T.
- **National Science and Technology Council (NSTC)** is a cabinet-level council chaired by the President, and comprising relevant cabinet secretaries and directors of major research agencies. NSTC is the main means for the President to co-ordinate S&T policy across the federal portfolio. NSTC has five goal-oriented committees which co-ordinate policy and budgets for multi-agency S&T activities. OSTP provides the secretariat. NSTC was established by Executive Order in 1993.
- **President's Council of Advisors on Science and Technology (PCAST)** established by Executive Order in 1990, helps NSTC secure private sector involvement in its activities. It currently comprises 18 members from the private sector and higher education.
- **Office of Management and Budget (OMB)** co-ordinates the overall budget process of the President. This includes the effective proposed federal R&D budget, but only insofar as this comprises the sum of departmental and agency research proposals. No separate R&D budget as such is advanced through OMB.

### *Budgetary process*

The US has a complex, lengthy and distinctive process of federal budget appropriations (mirrored at state level), with budgets for three consecutive fiscal years in operation or under way at any one time. The budget cycle begins with departmental and agency budget proposals submitted to OMB in the summer for the fiscal year beginning October of the following year. Early in the New Year, the President submits his consolidated budget request to **the legislative arm of government, Congress**. Here it filters through three levels of committees (budget, authorisation and appropriations committees), including both the House and the Senate. Noteworthy is the fact that there is at no point any overall Congressional review of the federal R&D budget as such; it is only ever dealt with in parcels through some 21 separate committees which have direct federal R&D policy or funding responsibility. Thus separate parts of departmental and agency budgets may be appropriated by different committees. At each stage of this process, proposals are reviewed and may be modified.

### *Advisory processes*

**A number of bodies offer advice** to the various research policy actors and have budgetary implications. The **National Science Board (NSB)**, appointed by the President, in addition to serving as the governing board of the NSF, provides advice to the President and Congress on matters of national science and engineering policy. The **National Academies** (the National Academy of Sciences and the National Academy of Engineering, and the Institute of Medicine), and their main operating agency, the **National Research Council (NRC)**, undertake a wide range of influential policy studies for government. The **American Association for the Advancement of Science (AAAS)** is a key professional organisation which undertakes policy analyses and organizes a comprehensive annual research convention addressing all fields of science. A wide variety of professional bodies and special interest groups are active within the

US, providing advice, and seeking support for different aspects of research. Through these and other means the research community contributes to the lengthy and complex chain of processes which results, ultimately, in federal allocations according to national goals and priorities.

### *Philanthropy*

The US has a strong philanthropic tradition, and major **foundations** provide significant funds for research institutions. A number are long established, such as the Carnegie Foundation; others more recent, such as the Hewlett Foundation (which recently gifted USD 400 million to Stanford University), and the Gates Foundation.

### **Review of policies and practices**

Several areas of policy and practice of particular significance for this project are: co-ordinating research policy and funding for the federal portfolio; level of public research funding and balancing of funding sources; balancing fields and types of research; ensuring a strong US born research community; minimising the costs of competition; and improving efficiency and quality in R&D.

### *Co-ordinating research policy and funding for the federal portfolio*

In the past, co-ordination and integration of policy have often been seen as a natural function or outcome of the interactions of the numerous and diverse stakeholders and interest groups. Effective co-ordination through shared information and collaboration in program development exists, at an informal network level and sometimes formally, between professional staff working within federal research agencies and departments. This network operates to allocate responsibilities for funding specific types of activities within fields where there is overlap of formal responsibilities. While this pattern and level of co-ordination accords with a social and political tradition that resists the concentration of power in the national capital and values dispersion of decision making and negotiated consensus, there are now signs of change, at least in the way certain policy makers are beginning to think.

The issue of co-ordination and overall priority setting within the federal portfolio has been debated for a number of years. For a number of reasons, including the perceived need to ensure continued public support for R&D, given other, alternate uses for limited funds, together with the growing cost of cutting edge research, ways are being sought to better co-ordinate federal R&D funding. The establishment of NSTC was a move in this direction, but the resources of OSTP, which provides its secretariat, are limited. Emphasis has been given by NSTC to co-ordinating the four multi-agency activities noted earlier, but the scale of operations and the large number of agencies make such co-ordination problematic. Also it appears that, over the years, NSTC has not consistently maintained participation by its most senior members, so its impact appears to have diminished.

Some degree of co-ordination of federally financed research was extensively discussed and supported with recommendations by the 1995 Press report of the National Research Council (NRC, 1995). Little action followed, however. In 1999, responding to a request from the House Appropriations Committee of Congress, with encouragement from OMB, the National Science Board (NSB) initiated a new study on budget co-ordination and priority setting for government-funded research. A key finding of the subsequent report was that 'the current system for priority setting in the Federal research budget lacks a coherent, scientifically based process for systematic review and evaluation of the broad Federal investment portfolio for effectiveness in achieving national goals' (NSB, 2001). Currently, allocations are based on faith in future payoffs, justified by past success. As the report indicates, this is difficult to defend against

alternative claims on the federal budget which promise concrete, more easily measured results, and which are supported by large and vocal constituencies.

The review recommended an improved process for research budget co-ordination and priority setting, building on the strengths of the current system and addressing weaknesses in data, analyses, and expert advice. The 'pluralistic framework for Federal research' was seen as a positive aspect of the system and increases possibilities for funding high-risk, high-payoff research.

Recommendations included:

- Placing a priority on investments: in areas which advance important national goals; in areas ready to benefit from greater investment; which address long-term needs and opportunities within the federal missions and responsibilities; which ensure world class fundamental science and engineering capabilities across the frontiers of knowledge.
- A five-year cycle of evaluation of outcomes of the federal portfolio for research in the light of federal goals for S&T.
- An annually updated report to the President and Congress outlining a well-defined set of the highest long-term priorities for federal research investments.
- OSTP, OMB and PCAST to have their resources augmented to facilitate the systematic gathering of data.
- Congress to have access to independent expert science and technology review, evaluation and advice, and the possibility through broadly based congressional forums (such as joint hearings of budget committees) of addressing the full federal portfolio for science and technology.

This report, on which action is yet to be taken, represents a step towards national level co-ordination of goals and priorities through a more rigorously conducted system of evaluation and reporting on impact; a fine-tuning rather than radical shake-up. Time will tell if there is sufficient will and capacity to act decisively on these proposals for greater co-ordination. Action has been lacking on co-ordination proposals in the past. The present proposals would significantly augment the operations of OSTP and the NSTC within the executive arm of government, and patterns of Congressional hearings would be shifted, but structures would remain essentially as at present. The essential framework of the federal research portfolio has been stable over a number of decades, with structural change limited to arrangements within the executive branch, with changes of Administration. There have, from time to time in the past, been significant structural proposals made to Congress, notably to establish a federal ministry of science. Such proposals appear never to have gained the support of Congress, however, and appear unlikely to do so in the foreseeable future.

While these recommendations focus on better co-ordination of research policy and funding at the federal level, there does not appear, at present, to be any mechanism to co-ordinate state and federal policy and funding on research. A forum exists for bringing together industry, universities and government in the form of the Government-University-Industry Research Roundtable (GUIRR) under the auspices of the National Academies. How closely foundations co-ordinate their research funding with state or federal bodies is unknown.

The issue of national goals is, as already indicated, by no means clear cut, nor can it be assumed that the social, cultural, economic and political forces underlying goal setting mesh well with the complex

apparatus of policy making and operations for research. This is indeed a challenge to the federal efforts to better co-ordinate research policy and funding.

### **Level of public research funding and balance of funding sources**

**Federal funding** for research increased continuously from the 1950s until the early 90s when, with the effective end of the Cold War, the military budget dropped significantly, there was a government-wide effort to reduce the deficit, and the federal research budget stagnated for several years. After five years of stagnation, federal research funding began to rise in 1998, and has continued steadily in each subsequent year, largely due to increased NIH funding. Also, from 2002, military spending has increased in line with the homeland security priority and the war against terrorism. As indicated earlier, the overall R&D budget proposed for 2003 sees a significant rise.

Although non-federal entities increased their national funding share from 60 to 74% between 1990 and 2000, federal funding supports 27% of the nation's total research expenditures, and 49% of basic research spending (Merrill, 2001, p.5). In general, federal funding for research has a longer time horizon and can be more stable than investments from other sources, but the political process is always uncertain.

As indicated above, **state level funding** for research has not to date been significant and has generally been mission focused, although there are moves which may bring significant contributions from some states. The National Academies' Committee on Science, Engineering and Public Policy (COSEPUP) has established an exploratory project on the role of state in funding research, noting science and technology strategic planning in a number of states during the nineties, and initiatives such as: Michigan Economic Development Corporation funding of the Life Sciences Corridor Initiative; Florida's USD 1.7 billion Lawton Chiles Endowment Fund; Ohio's Biomedical Research and Technology Transfer Commission to oversee a similar fund; and the California government's plan to establish the California Institutes for Science and Innovation at campuses of the University of California.<sup>5</sup>

Turning to the **higher education sector**, the American Association for the Advancement of Science (AAAS) analysis indicates that higher education performs just over half of federally funded basic research. 58% of university R&D is funded from federal sources, with most of the rest from institutions' own funds. Relatively little support for higher education research comes from industry, 7%, although this is growing (rapidly) (Koizumi, 2002). Nearly two thirds of federally funded R&D in higher education is from NIH. This dominant funding role affects the mix of disciplines in R&D portfolios, with life science now representing 58% of all R&D in higher education. Engineering and the physical sciences account for 15% and 9% respectively of total university R&D, both a decline of 1% from the previous year.

Although federal research funding overall for higher education appears to have been maintained, public universities have found other sources of income squeezed, notably their state funding which is linked to their teaching mission. Most states experienced financial difficulties during the eighties and nineties cutting appropriations for higher education, and state universities as a consequence, have had to look more

---

5. The Michigan initiative is a billion dollar effort funded from the state's settlement with the tobacco companies. Florida's initiative, to support biomedical research, is also funded from tobacco settlement revenues. In California, the current financial crisis willing, the state government will contribute USD 300 million over four years, as part of a three way partnership with the University of California and industry which together are expected to match each state dollar with two from non state sources. The Institutes will address basic and applied cross disciplinary research focusing on large scale problems where scientific advances may spur future economic growth. The initial four multicampus Institutes have been agreed.

to generating their own resources. Industry and fund-raising are important sources, but the key source has been tuition fees which grew by some 158% between 1980-96 in 64 state universities. While the appropriations were more or less restored by the end of the decade, a higher tuition fee regime appears to have been established (Geiger, 2000).

Private universities have not been affected to the same extent as public universities by state level budgetary difficulties, but they equally face the question of the limit to public acceptance of tuition increases. Between 1980-96, tuition fees in 33 private universities grew by 114% (from a much higher base than that of state universities), but study costs have been offset (as to a lesser degree in state institutions) by a combination of institutional grants or tuition discounts and the massive growth of federal loans (from USD 5 billion in 1978 to USD 30 billion in 1996). While this strategy of 'high-tuition/ high-aid' has succeeded to date for the private universities, Geiger (2000) notes that it has caused growing stratification, and queries the longer term sustainability of this approach for the system as a whole.

**Federally funded public research institutions** do not appear to be facing as severe a funding difficulty as the state universities, given the relative health of the federal research budget. But, depending on the agency with which they are associated, different approaches hold to the funding of these agencies. For example, DOE laboratories compete only amongst themselves for DOE intramural Science funds, universities competing for the extramural budget; whereas NASA laboratories compete directly for funds with universities.

Each lab is entrepreneurial in seeking competitive funding from different sources. Within this sector, no fixed pattern is evident. By way of example, DOE's Lawrence Berkeley Laboratory, a multiprogram lab (owned by DOE, but managed by the Office of the President, University of California under contract), is not block funded in the sense of having a base funding whose use it can decide. The Lab develops its project based budget proposals on an annual cycle (although certain activities may be for a 5 year period), so there is always a certain degree of budget uncertainty. As the Lab does not have free funding, staff are paid through overheads on project grants (a rate of 41% is used). As with the federal budget cycle discussed earlier, labs are constantly working with budgets for three fiscal years at a time.

Although it is convenient to talk about a 'network' of institutions belonging to such agencies as DOE, DOD etc, funding relationships are directly between the institution and the funding agency – there is no intermediate central level which co-ordinates the institutions into an organic network, as exists in some other countries. There are, however, a wide range of co-operative arrangements between different labs and institutions relating to particular projects and programs and initiated at a grass-roots level.

### **Balancing fields and types of research**

**Fields of research:** During the 1990s federal research funding for the physical sciences and engineering fell by comparison with research in the life sciences. While the fall in funding for physical sciences and engineering was in part due to the overall drop in funding for the main sponsors of these fields of research (DOD, DOE) with the effective end of the Cold War, a detailed study by the Board of Science, Technology and Economic Policy (STEP) of the National Academies, indicates that reductions went beyond these departments. The funding reductions were substantially the outcome of decentralized decision making by officials in various departments, agencies, and congressional committees, adjusting resources to agency mission needs in a constrained budget environment (Merrill, 2001, p.5). This study pointed to a further consequence of weakness in overseeing the federal research portfolio and reinforced NSB calls for better monitoring of the research portfolio to enable necessary adjustments to ensure breadth of research fields are funded within the portfolio as a whole. Data studied suggested that even a reinstatement of earlier funding levels would not lead to the former breadth being reinstated – a shift in the balance had occurred over the 90s.

The STEP study also drew attention to the fact that a number of the fields where funding and graduate students have dropped have been those on which much vaunted recent advances in the life sciences have depended, including chemistry, physics, electrical engineering and chemical engineering, all fields with less funding at the end of the 1990s than at the beginning. Thus it has been argued that allowing such a drop in research funding jeopardizes the current priority fields (based on historical patterns) quite apart from the argument of keeping a range of research fields current because of the inherent unpredictability of scientific research in terms of where the next breakthrough will come.

**Interdisciplinary research:** While the cutting edge of research in many areas is increasingly where disciplines meet, fostering interdisciplinary research remains problematic at many levels. Many existing structures, including traditional university organisation, and the bulk of current performance indicators, continue to favour disciplinary research, although major funding opportunities (*e.g.* NIH, NSF) are interdisciplinary.

Within most universities, interdisciplinary research continues to be encouraged amongst staff who frequently owe a primary allegiance to a disciplinary base in a faculty or department. Thus, research centres and institutes become secondary allegiances, and secondary sources of funding for research. The question remains for most institutions of how to build a real interdisciplinary culture, as opposed to essentially grouping together the research from different disciplines. This is a progressive process, often requiring delicate facilitation, and is unevenly spread through research fields. Overall mode 2 research is growing. Various organizational models exist at universities to foster interdisciplinary research, with the models at MIT, University of Michigan and Carnegie Mellon University being highly regarded.

**Types of research:** Turning to the type of research funded from federal sources, AAAS analysis of the Bush FY 2003 budget request indicates that basic research would increase by 7.9% to an all-time high of USD 25.5 billion, largely because of a 9% increase for basic research in NIH. NIH would provide more than half of federal basic research (56%). Excluding NIH, basic research through other agencies would rise by 6.5%, although much of this is attributed to a 20% jump in NASA basic research, relating more to accounting changes than programmatic increases.

Total federal funding for basic and applied research together, would increase by 6.5% to USD 51.0 billion. Excluding the NIH increase, however, other federal research would fall 0.2%. Applied research at NIH would grow disproportionately to basic research, however, because the high-priority areas of cancer and counter-bioterrorism involve significant applied rather than basic research. An 11.9% increase in development to USD 55.2 billion mainly reflects funds for weapons systems for DOD (Koizumi, 2002).

Defence and non-defence R&D have rather different characters. Some 87% of defence R&D would constitute development, with 10% applied, and just 2% basic. The very high development costs are related to testing and evaluating weapons systems, which are very expensive compared with other types of R&D. For non-defence R&D, basic research would be the largest category, with 38% of research applied, and only 8% development.

The US has maintained a strong element of basic research within its overall federal research profile. Indeed, the STEP study showed that during the 90s, when research budgets dropped, basic and university research tended to be protected relative to applied research and other performers.

There is considerable debate in the US about the adequacy for contemporary policy of the **traditional distinction between applied research and basic research** where basic research is seen as essentially curiosity-driven. The report of a major conference focused on this question, identifying two examples of 'use-inspired basic research' which it commended as a third category to be built into official US research policy and funding processes (Branscomb *et al.*, 2001; Stokes, 1997). The two examples discussed were

the approaches of the National Cancer Institute and of the NSF to basic research in support of national goals. The term 'Jeffersonian science' was used for the 'use-inspired' orientation, and contrasted to 'Newtonian' or curiosity-driven science, and 'Baconian' or applied science. How far the Jeffersonian orientation will become part of the formalized categories of research funding remains to be seen, but there is no doubt that research policy and funding are moving in a direction which will increasingly include national priorities and goals among the criteria for research funding.

It is acknowledged by its proponents that the above distinction between the two forms of basic science (Jeffersonian and Newtonian) is based on the intent of the researcher, and that in practice, the consequent research undertaken may be very similar. Thus this distinction is rather different from the Mode 1, Mode 2 distinction drawn by Gibbons which focuses on the processes through which research is undertaken (Gibbons, 1997). [It is, however, the case that much Jeffersonian research could fall into the Mode 2 style, being problem-focused and most probably interdisciplinary.]

### **Ensuring a strong US born research community**

Over a number of years a situation has developed in which the US has become dependent on foreign born science and technology students to fill available graduate places and post docs. This increases the more advanced the degree. In 1999, 10% bachelor's degree holders were foreign born, 20% for master's degrees, and 25% or greater for doctorates, with a much higher figure in some engineering and computer science fields (NSF, 2002). This appears to be partly a demographic question of smaller cohorts of those US born groups which have a tradition of university study in these fields (majority males), as well as a change in study choices (away from certain sciences and engineering) for reasons not well understood. Until recently, available places have been filled from foreign born students (now predominantly Chinese and Indian). In recent years there has been a major effort to increase the number of both female and minority US born students studying in these fields, and some success is becoming evident, albeit, with minority students, from a small base. There is currently a greater supply of than demand for graduate places by US born students. There is also considerable variability in the patterns of study by field concerning graduate students and post docs. Post docs fit differently into the career structure of different fields, having become a virtually regular part of the career in some fields of science.

Given the current priority of homeland security, there is some concern that dependence on foreign born scientists may be a point of vulnerability. Several developments appear likely: foreign born students may be restricted in relation to particular research labs or fields of research; student visas are to be processed through Washington DC, and closer attention may be given to certain categories; the ceiling for work visas in the coming year is being reduced to 65 000.

The more significant concern, however, as identified in the most recent NSF Science and Engineering Indicators (NSF, 2002), is that while at present the US is an attractive destination, and some half of foreign graduate students remain in the US to work, over time, the US may become a less attractive destination. As living standards improve in developing countries, students may increasingly wish to return home to participate in further development; also other industrialised countries, particularly in Europe, are developing competing international centres of scientific, technical and engineering excellence. In this situation, the US needs to ensure a well-trained domestic research workforce.

The question of increasing the numbers of students enrolling in particular fields is, however, not a short-term one, and strategies need to include a K-12 focus. NSF has been working in this direction for a number of years as have a considerable network of science educators through professional networks (AAAS, see Black and Atkin, 1996). The long term and diffuse nature of the outcomes of such interventions makes it

difficult to judge their success. But it is clear that without such efforts the situation is unlikely to turn around.

Most research students are supported by grants or scholarships, frequently involving tutoring or working as an assistant on faculty research projects. When the employment market is good, fewer students are attracted to research degrees. In order to increase the attraction of research training, NSF, which funds a large proportion of graduate student stipends, has increased their level this year by a significant amount.

A common difficulty for staff is providing continuity of funding for those graduate students working as research assistants. Project funding is not generally coterminous with graduate student courses, and staff find themselves needing to be creative in drawing funds from different projects to provide continuity for individual graduate students.

In US there is now no mandatory retirement age, so that academics can (and some do) continue working well into their seventies (and beyond). Far from constituting a problem for recruitment, the ability of the university to recall retirees/emeriti gives them considerable flexibility, for example in organising directorships of various programs or institutes on a temporary basis. Emeriti are paid from a different income stream, freeing up money for new recruitment, while retaining the input of experienced staff.

### **Minimising the costs of competition**

A striking feature of the competitive setting of US science is the importance that different **rankings** have come to hold for research performing institutions. Quality is an issue of relativism and standing among peers. Different rankings act as drivers of competition between institutions and have become an important driver of institutional strategy. Thus the external environment directs internal strategies. By way of example, the Penn State strategic plan for research draws attention to the university's position in no less than twelve different rankings against other universities (e.g. NSF), using these as major motivations for planning directions. And this is probably a fairly typical approach among universities. Institutions are continually striving for a competitive edge over rivals – to maintain existing advantage, and seek further improvement. Competitive funding is also seen as a means of increasing efficiency and productivity.

When does competition reach an unproductive extreme? It is interesting to note that the Carnegie Classification of Higher Education Institutions, which was first developed in the 1970s and which identified research intensive universities as the peak of its classification of the nation's 3 000 + higher education institutions, is in the process of being fundamentally reorganised. Amongst other things, it is believed that the current classification has encouraged uniformity rather than diversity amongst institutions. An unintended consequence of the classification has been its use as a ranking rather than classification system. Other rankings, however, are also influential within the US (e.g. *US News and World Report*).

Is there a safety net for those who lose out in competition? How adequate is it? There is evidence of a limited move toward greater concern for geographic and institutional spread in recent years. While there is an official discouragement of **earmarking**, the process has, however, grown in recent years. Earmarking refers to a non-competitive process whereby in the appropriations process, Congress earmarks certain funds for defined purposes, generally as broad institutional support. Earmarks are often the outcome of the efforts of individual members of Congress on behalf of their constituents, and thus are geographically and politically related.

While the particular practice of earmarking may have a number of undesirable aspects, its resurgence points to the recognition of a need generated by an increasingly competitive environment to consider both those institutions at a competitive disadvantage and broader social considerations. It implicitly questions

whether the market forces of competitive research funding should be allowed to be the sole determinant of institutional research profiles, or whether there are broader system needs which argue for supporting a certain infrastructure of research performing institutions. There are a range of reasons why certain research performing institutions may be disadvantaged, including locational factors (geographic position, peripheral location with respect to the major research nodes and centres of industry) and institutional factors (definition of mission; adequacy and competence of staffing; competence and flexibility of management; adequacy of facilities, *etc.*).

While the balance in the US at present favours an increasing reliance on the competitive market approaches to research funding (*e.g.* NSF's widely respected merit based award processes, seen as a means of backing quality and efficiency), there is also a piecemeal recognition of overall system needs in the sense of an unwillingness to allow the full consequence of market forces to affect all institutions. Only a few bodies address these questions, however, and only in a limited fashion. Thus, certain members of Congress work to enable earmarks to support institutions within their constituencies (in the main). On a more systematic, though limited, basis, NSF funds the Experimental Program to Stimulate Competitive Research (Epscor) which has, for twenty years, provided science support for institutions in those states receiving less than 1% of NSF funding. This program, which aims to help states and institutions develop the ability to compete successfully in the 'major leagues', is essentially of a capacity-building type. Feller (1999) has identified strategic options for enhancing competitiveness.

While questions of the imbalance in the fields of research have been flagged for policy attention, support for and development of a **nationally distributed system of research institutions** appears to be a gap in current debates. This is a difficult issue for a country with such distributed decision-making powers, including at both state and federal levels.

### **Improving efficiency and quality in R&D**

The established processes of merit-based research funding are time consuming, and demanding of human resources. **Streamlining** these processes is of interest both to research funders and research performers. Recent developments are of particular interest. First is the Federal Demonstration Partnership (FDP), now entering its fourth phase. This unusual and interesting mechanism provides members with the opportunity to work together to streamline and simplify the administration of federally funded research grants. Within an association of twelve federal agencies, 65 research institutions across 14 states and seven professional organizations (during the third phase, 1996-2001) new and more effective ways of managing some USD 15 billion of federal research grants was identified, tested and implemented. A uniform contractual relationship between the federal agencies and the universities replaced the existing plethora of terms and conditions for federal research grants, enabling money to be moved quickly, and for sub-awards (rather than subcontracts) to be made to partner institutions in the case of collaborative research. Electronic research administration was piloted, and a Fastlane experiment established with NSF. Electronic awarding of research grants (eRA) now occurs with NSF and NIH.

The FDP is convened by the Government-University-Industry-Research Roundtable (GUIRR) of the National Academies. Although the fourth phase will see an expanded membership, this activity still deals with only a small proportion of research active institutions, although the major federal funding agencies are participating. The challenge is to generalise the benefits.

The salience of research in university profiles has led to the **strengthening of strategic research planning within institutions** and the growth of institutional structures to manage research; also the need to match funding, collaborate with industry, develop science parks *etc.*; the importance of research for status, and attracting students. Notable has been the growth of the office of Vice President Research and associated

administrative support. Research is becoming more bureaucratized at the institutional level. The development of strategic planning which identifies priorities at an institutional level has, however, led to within-institution tensions with researchers who have traditionally defined and undertaken their own research work.

Another dimension of research quality is the **growth of regulation and compliance measures** within the US, notably in relation to research on human and animal subjects. This comes as a result of past problems and consequent court cases. Compliance issues are a growing concern for research administrators in research performing institutions. Regulations are rising in all areas of research, with increase in public pressure and concern particularly over work with human subjects, animals and biological and chemical agents. The risk of litigation is real, and the perception is that failure to comply can jeopardize all research activity by placing an institution in an exceptional category. The growth of compliance requires familiarity on the part of research staff with new requirements. In addition to conforming with federal and state regulations institutions may choose to become accredited to non-profit accreditation organizations, for example the Association for the Accreditation of Human Research Protection Programs, and the Association for Assessment and Accreditation of Laboratory Animal Care International. Such associations help institutions reach performance standards above state and federal requirements. Thus, compliance is becoming an increasingly important consideration, adding complexity to the research environment, with important consequences at institutional level as well as at the level of individual researchers.

## Conclusion

A defining feature of the US research system is pluralism. Changes in one sector or field may find few if any echoes in others. With this important caveat in mind it is, nevertheless, possible to identify several change forces which have a broad impact. Most striking of the very recent ones is the mobilization of national effort under the umbrella of national security. Research performance will be increasingly attuned to anti-terrorist, military and security goals, reflecting a changing global environment as much as forces and pressures within the country itself. It can be expected that the long drawn out efforts to improve policy coherence and co-ordination of effort will be coloured by security concerns in addition to the factors already mentioned. The drive for enhanced competitiveness and efficiency and improved quality can be expected to continue with implications for institutional and program management, and accountability. Greater emphasis on transparency and the public interest means more attention by the research community to ethical, social and political demands – science in context, as it were.

The levelling off or drop in state funding for universities during the 1990s led to greater reliance on institutions' own sources, including tuition, now reaching the limits of acceptability. There has also been a greater interest in seeking industry funding for public research performers, which has raised controversial issues such as commercialisation on campus – questions of academic freedom and how far universities can go in their links with commercial organizations, without themselves becoming compromised.

Overall research funding from federal sources have been strengthened with a particular bias to biosciences over the past five years, and a current resurgence in military R&D budgets. While dramatic changes in the research environment are not at present evident, the mix of long standing concerns and initiatives and a rapidly changing global economic and security environment are sending signals which will affect all research performing institutions.

While the US has a national research system within which decision making power is widely distributed; it is in no sense monolithic. Rather it reflects deeply held convictions about pluralism and diversity shared with public-private roles and responsibilities. As a system it enables multiple sources of initiative and empowerment with respect to research activity, and proved to be the most successful research system in

world terms during the last quarter of the twentieth century. The structure of the research system has remained stable over the past half century, as has substantial federal support for R&D. But there are perceived major challenges which remain to be met in a climate where the longstanding US predominance in research and development appears no longer to be taken for granted. Key perceived challenges are: the need to ensure an adequate and continuing supply of US born researchers; and the sense that there is a need to achieve better national level co-ordination in research policy and practice.

## ANNEX

### ACRONYMS

AAAS	American Association for the Advancement of Science
DOD	Department of Defense
DOE	Department of Energy
FDP	Federal Demonstration Partnership (GUIRR)
FFRDC	Federally Funded Research and Development Centers
FS&T	Federal Science and Technology budget
GPRA	Government Performance and Results Act (1993)
GUIRR	Government- University- Industry Research Roundtable (National Academies)
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NRC	National Research Council (National Academies)
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council (White House)
OMB	Office of Management and Budget (White House)
OSTP	Office of Science and Technology Policy (White House)
PCAST	President's Council of Advisors on Science and Technology (White House)
STEP	Board of Science, Technology and Economic Policy (National Academies)

## **VISITS**

### **Pennsylvania State University**

Robert T. McGrath, Associate Vice President for Research, Director of Strategic and Interdisciplinary Initiatives

Jeffrey R. Shallenberger, Assistant Director, Materials Research Institute

Robert Killoren, Assistant Vice President for Research and Director of Sponsored Programs

Irwin Feller, Professor of Economics

Roger Geiger, Professor of Higher Education, and Head, Higher Education Program, Department of Education Policies

Joan Schumacher, School of Graduate Studies.

### **National Institutes of Health**

Stephen I. Katz, Director, National Institute of Arthritis and Musculoskeletal and Skin Diseases

R. Anne Thomas, Associate Director for Communications, Office of Communications and Public Liaison

### **National Science Foundation**

Michael Sieverts, Senior Policy Analyst, Budget Division

Rolf Lehming, Director, Science and Engineering Indicators, Division of Science Resources Statistics

Jean Pomeroy, Senior Staff Associate, Policy

### **The National Academies**

Stephen A. Merrill, Executive Director, Board of Science, Technology and Economic Policy

Deborah D. Stine, Director, Office of Special Projects, and Associate Director, Committee on Science, Engineering and Public Policy

Merrilea Mayo, Director, Government- University- Industry Research Roundtable

### **National Aeronautics and Space Administration**

Ann B. Carlson, Special Assistant for Science Policy, Office of the Chief Scientist

Angela Phillips Diaz, Director, Human Space Flight and Research Division, Office of External Relations

### **Department of Energy**

Inja K. Paik, Senior Economist, Office of Policy and International Affairs

Wm J. Valdez, Director, Office of Planning and Analysis

### **US Department of State**

William R. Gaines, Director, Office of Science and Technology Co-operation

### **University of California, Ernest Orlando Lawrence Berkeley Laboratory**

Todd Hansen, Planning Analyst, Office for Planning and Development

Rob Johnson, Head, Initiatives, Office of the Director

**University of California, Berkeley**

John Douglass, Center for Studies in Higher Education

Sheldon Rothblatt, Professor Emeritus of History and former Director, Center for Studies in Higher Education

**University of California, Office of the President**

Jeffrey R. Hall, Assistant Director, Policy and Projects, Office of Research

Scott MacDonald, Senior Policy Analyst, Office of Research

**Stanford University**

Geoff Grant, Associate Vice President, Office of Research Administration

Myron Atkin, Professor of Science Education

Ann George, Assistant Dean of Research

## REFERENCES

- Black, P. and Atkin, M. (1996) *Changing the Subject. Innovations in Science, Mathematics and Technology Education*, London, Routledge with OECD.
- Bowen, F.M., Bracco, K.R., Callan, P.M., Finney, J.E., Richardson Jr, R.C., Trombley, W. (1997) *State Structures for the Governance of Higher Education: A Comparative Study, Executive Summary*. [[www.policycenter.org/comparative/comparative2.html](http://www.policycenter.org/comparative/comparative2.html)]
- Branscomb, L. Holton, G. and Sonnert, G. (2001) *Science for Society, Cutting-Edge Basic Research in the Service of Public Objectives: a Blueprint for an Intellectually Bold and Socially Beneficial Science Policy. A report on the November 2000 conference on basic research in the service of public objectives. Sponsored by the David and Lucille Packard Foundation and the Alfred P. Sloan Foundation*.
- Clough, G. W. (2002) 'National priorities for Science and Technology – a View from the Academic Sector'. Georgia Institute of Technology. Mimeo.
- Coward, H.R. (2000) *Final Report: Symposium on International Models of Budget Coordination and Priority Setting for S&T*, Washington DC, SRI International.
- Department of Energy (2000) *DOE Research and Development Portfolio, Overview*, Washington DC, USDOE.
- Douglass, J.A. (2000) 'A certain future: Sputnik, American higher education, and the survival of a nation' in Launius, R.D., Logsdon, J.M. and Smith, R.W., eds. *Reconsidering Sputnik – Forty Years Since the Soviet Satellite*. Pp.327-363, Amsterdam, Harwood.
- Ernest Orlando Lawrence Berkeley National Laboratory (2001) *Institutional Plan FY 2002 – FY 2006*, LBNL/PUB-5468, Berkeley, The Laboratory.
- Federal Demonstration Partnership (n.d. but 2000) *2000 Annual Report – June 1999 through July 2000*, Washington DC, National Academy Press.
- Feller, I. (1999) 'Strategic options to enhance the research competitiveness of EPSCoR universities', Paper presented to the AAAS workshop on academic research competitiveness, 1999, [[www.aaas.org/spp/dspp/RCP/epscor/Feller.html](http://www.aaas.org/spp/dspp/RCP/epscor/Feller.html)].
- Geiger, R. (2000) 'Politics, Markets, and University Costs: Financing Universities in the Current Era' *Research and Occasional Paper Series: CSHE.4.00*, Center for Studies in Higher Education, University of California Berkeley, Berkeley, UCB.
- Gibbons, M. (1997) *What kind of university? Research and teaching in the 21<sup>st</sup> century*, Beanland Lecture 1997, Victoria University of Technology, Melbourne, VUT.

- Keith, R. (1997) A Brief Introduction to the Federal Budget Process, CRS Report for Congress, [[HTTP://cnie/org/NLE/CRSreports/information/info-6.cfm](http://cnie/org/NLE/CRSreports/information/info-6.cfm)].
- Koizumi, K. (2002) 'R&D Trends and Special Analyses' in AAAS Report XXVII: *Research and Development FY 2003*, Chapter 3, [[www.aaas.org/spp/dspp/rd/03pch3.htm](http://www.aaas.org/spp/dspp/rd/03pch3.htm)].
- Marburger, J. (2002) 'Science and technology in a vulnerable world: rethinking our roles' Keynote address to 27<sup>th</sup> Annual AAAS Colloquium on Science and Technology Policy, [[http://www.ostp.gov/html/02\\_4\\_15.html](http://www.ostp.gov/html/02_4_15.html)].
- Merrill, S.A. (2001) *Trends in Federal Support of Research and Graduate Education*, National Research Council, Board on Science, Technology and Economic Policy (STEP), Washington DC, National Academy Press.
- National Aeronautics and Space Administration (NASA)(2000a) *Aeronautics and Space Report of the President, Fiscal Year 2000 Activities*, Washington DC, NASA.
- National Aeronautics and Space Administration (NASA)(2000b) *Strategic Plan 2000*, Washington DC, NASA.
- National Research Council, Committee on Criteria for Federal Support of Research and Development (1995) *Allocating Federal Funds for Science and Technology*, (The Press Report) Washington DC, National Academy Press.
- National Science Board (NSB) (1997) *Government Funding of Scientific Research*, Working paper NSB-97-186, Arlington, VA, National Science Foundation.
- National Science Board (NSB) (2001) *Federal Research Resources: A Process for Setting Priorities*, (NSB 01-156) Washington DC, National Science Foundation.
- National Science Foundation (NSF) (2001) NSF Survey of Research and Development Expenditures at Universities and Colleges, Fiscal Year 2000, Arlington VA, NSF.
- National Science Foundation (2002) Science and Engineering Indicators – 2002, Vol.1, Arlington VA, NSF.
- National Science Foundation (n.d. but 2002) Summary of FY 2003 Budget Request to Congress, Arlington VA, NSF.
- OECD (2000) Science, Technology and Industry Outlook, Science and Innovation, Paris, OECD.
- Office of Management and Budget, Executive Office of the President (2002) The President's Management Agenda, Fiscal Year 2002, [[www.whitehouse.gov/omb/budget](http://www.whitehouse.gov/omb/budget)].
- Office of Management and Budget (2002) President's 2003 Budget Request.
- Pennsylvania State University (2001) *Research/Penn State*, September.
- Pennsylvania State University, Office of the Vice President for Research (2002) *Strategic Plan 2002-2005*, State College, PA, Penn State University.

Popper, S.W., C.S. Wagner, D.L. Fossum, and W.S. Stiles (2000) *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review*, (DRU-2286-NSF), Washington DC, RAND Science and Technology Policy Institute.

Richardson, R. (1997) *State Structures for the Governance of Higher Education, California Case Study Summary*, Technical paper prepared for State Structures for the Governance of Higher Education and The Californian Education Policy Center, Californian Higher Education Policy Center.

Schindel, D.E. (2001) *United States Survey Response, OECD/DSTI Steering and Funding Public Research Organisations project*.

Teich, A.H. (2000) 'Renewing the Federal Government-University Research Partnership for the 21<sup>st</sup> Century' *AAAS Science and Technology Policy Yearbook 2000*.

Stanford University (2001) *2001 Annual Report*, Stanford, The University.

Stanford University (2002) *Stanford Facts 2002*, Stanford, The University.

Stokes, D.E. (1997) *Pasteur's Quadrant: Basic Science and Technological Innovation*, Washington DC, Brookings Institution.

University of California (2001) 'California Institutes for Science and Innovation: A foundation for California's future', Overview brochure.

University of California, Office of the President, Office of Research (2001) *Research Funding at UC, Fiscal Year 2001*.