PART 9

Issues of the Day

Three timely chapters make up Part 9, including a discussion on European science and technology (S&T) by Hubert Markl, the president of the Max Planck Society, an excerpt from a thought-provoking report on basic research in the service of public interest, and an address on the impact of terrorism by Rep. Sherwood L. Boehlert, the chairman of the House Science Committee.

In Chapter 35, Hubert Markl discusses the state of scientific development in the Max Planck Society, as well as the overall state of research and development (R&D) and S&T in Germany and the European Union (EU). He believes that Europe is moving in the right direction when compared to the United States, and while there is potential to follow the United State's lead, it is also important to "go in our own ways." Markl points to the importance of the EU's diversity arguing that it "is one of the key notions for the future of our societies and economies." He continues, "Europe has great diversity, not only of cultures and people, but also of policies and pre-conceptions, and of historically influenced lines of development." Markl also assures readers that German politicians are well aware of the importance of S&T and that the German budget for S&T is actually better per capita than that of the United States if one excludes the Department of Defense's and National Institutes of Health's budgets.

An excerpt from "Science for Society: Cutting-Edge Research in the Service of Public Objectives: A Blueprint for the Intellectually Bold and Socially Beneficial Science Policy," comprises Chapter 36. The report, prepared by Lewis M. Branscomb, Gerald Holton, and Gerhard Sonnert of Harvard University, is based on the Conference on Basic Science in the Service of Public Objectives held in Washington, DC, in November 2000, and contains appendices with selected conference presentations not included here. In their report, Branscomb *et al.* stress the need for a science policy based upon the concept of use-inspired basic research, or "Jeffersonian science." They hold that the current system, which is based on the dichotomy of basic and applied research, is missing a necessary element. Accordingly, "the addition of a third mode—basic science that is targeted in an area of important societal objectives, or

Jeffersonian science—is likely to bring about specific major advantages over the current system." The authors believe that the improved system will enable science to do even more, and more quickly, for society; will make the link between basic research and public objectives more obvious, and in doing so, provide the public with a greater appreciation of the benefits of science; and will enhance science's claim to moral authority.

The *Yearbook* concludes with a chapter by Rep. Sherwood L. Boehlert, who discusses the impact that the terrorist attacks of September 11 have had on academic research and development (R&D). He reminds readers that just as in previous times of crisis, the nation will eventually turn to its colleges and universities for help: "We look to our universities for leadership, for ideas, for information, for education and training, and, if worst comes to worst, for soldiers." Although Boehlert does not believe that R&D in general should be changed, he does feel that there are a few areas that need additional focus, especially research on computer security, better protecting the nation's physical infrastructure, and preventing or responding to chemical, biological, or nuclear attacks. "We need to draw on, and shore up, the strengths of our major institutions…not just to prevent future attacks, but to ensure that our nation remains a beacon of freedom, openness, opportunity, innovation, and prosperity."

35 R&D in Europe: Uniting Forces, Moving Ahead

Hubert Markl

This chapter discusses the present state of scientific development in the Max Planck Society, as well as the present state of R&D and science and technology (S&T) in general in Germany and the European Union.

The U.S. budget for FY 2002 will show a 6.1 percent increase ($5.6 billion) for science and technology. The National Institutes of Health (NIH) alone will receive a 13.6 percent increase ($2.8 billion), if it all goes as planned through Congress. This increase alone is more than the whole of the combined budgets of the Max Planck Society and the German Research Council (Deutsche Forschungsgemeinschaft), and a couple of other German institutions of similar kinds. That says a lot. The $2.3 billion that NIH spends on intramural research is more in absolute numbers than all the spending in medical research in my country. And Germany is not exactly a small country in that respect. We are indeed keenly aware of the competition out there. No wonder one is inclined to call NIH, the National Institutes of Wealth!

Of course, figures and financial budgets are not the whole truth. Behind these is the intellectual force. It is the people, especially the young people, who work in these areas that change money into scientific progress. Of course, they work in science and technology because they are paid to work there. But we must remember this important correlation between the budget figures and the work force.

Where is Europe moving in comparison with the United States? It is moving in the right direction. We estimate that up to 25 member states will soon unite forces. We see a tremendous potential to follow America's lead, but also to go in our own ways. Diversity is one of the key notions for the future of our societies and economies. Europe has great

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Hubert Markl is president of the Max Planck Society. This article is based on remarks delivered at the 26th Annual AAAS Colloquium on Science and Technology Policy, held May 3–4, 2001, in Washington, DC.

diversity, not only of cultures and people, but also of policies and preconceptions, and of historically influenced lines of development.

We have a lot of work ahead of us, and it will not be fast or easy. It will be two steps forward and one step back as always, but I think we are moving in the right direction. We will be able, in the future, to offer the United States and other countries like Japan, China, Russia, or India, a more coherent entity (though diversified in its strengths) for tackling together joint global problems.

The Max Planck Society

We regard ourselves as well-known in the world. We stand for premium fundamental research in Germany, and we will do everything we can to continue to do so. We have gone through very interesting times in the last decade. As a consequence of German reunification, we had the wonderful opportunity to open up 20 new institutes in the former DDR (German Democratic Republic). They are working in some of the most interesting areas. What is very gratifying about the consilience (or, in a very classical sense, the unification), is that now we talk about science again in one word and with the same vocabulary.

If you visit the Max Planck Institute for Evolutionary Anthropology in Leipzig, for example, you will see that the work goes far beyond the sciences. You will see people working in molecular biology, evolutionary psychology, linguistics, and primate behavior. Altogether, they try to understand what it means that human beings have evolved both biologically and culturally. We have many institutes with "multi" names, like biogeochemical systems. More and more we strive to overcome the division into separate disciplines and rather define scientific work by the problems addressed. To solve problems we need contributions from many disciplines. Merging disciplines is a very dynamic process, and it makes possible rapid progress in the natural sciences and beyond. For example, a new institute in Dresden is closely collaborating with experimental institutes trying to not only understand complexity from a physicist's point of view, but also biology, economics, in one word self-organization in all kinds of systems. This is a wonderful opportunity.

Since we did not expand our budget, we had to retract in other places, mainly in the former Federal Republic of Germany (in the "old Bundesrepublik"). And we had to close down institutes. I got plenty of letters saying, "No, you mustn't close this institute. It was one of the places where I got my postdoctoral training, and therefore alone, it should stay there forever." Certainly sad enough, but such is life, even at institutions.

In spite of closing some institutes, we have overall managed to keep hold of the spirit that drives research. The decision on whether or not we ever dismantle an institute again is not dependent on whether some Noble prize-winning scientist has put his or her foot in a place. It does depend on whether we can keep the spirit that drives first-rate research alive, and transmit it to the new generation. I think we are not doing too badly there.

I will mention just one development. We internationalize in the Max Planck Society to an amazing degree. Although we do research in German institutions, I cannot say any longer that our work is strictly a German scientific contribution, because I have now approximately 25 to 30 percent foreigners among the 250 directors of our institutes. Sixteen are U.S. citizens. The non-permanent scientific work force in our institutes is almost 50 percent foreigners (of course, many come from the European Union). This is wonderful for us because when you transplant people and help them to build up an institute, they bring with them a huge network of connections to all the places they have been before.

We even have institutes where very few people speak German, which raises a problem when people call from outside wanting to find someone they can address in German. They resent it if everyone speaks only English with them. So, we have minor problem. But this is the only way we can do it, since we may have people of 20 nationalities in one single institute!

In the past, the Max Planck Institutes had an inclination to live too much in splendid isolation from the university world. So we connected all the new institutes on campus with good university partners. We are now building up, rather rapidly, a new system of collaboration between Max Planck Institutes and universities. We have established new cooperative agreements with universities that will become centers for graduate education. We call these the International Max Planck Research Schools. All teaching will be in English only. Schools get money only if they enter into a very formal agreement, which defines the level of cooperation and the curriculum, so everyone knows through the Internet what is going on in each school. The universities, either one nearby, or the person's home university will award the degrees. But the training students receive, and the opportunities for doing research we offer, are the same from institution to institution. More than 50 percent of the participants in these research schools must come from abroad.

I thought it would be difficult to set up these research schools, but we have established almost 20 by now, and it was not difficult at all. When we advertised worldwide, we almost immediately received very interesting applications from all over the world. Many came from Middle Eastern Europe, which was one of our intentions. After the fall of the Iron Curtain, this is a wonderful opportunity to work together to help educate the elite in that part of Europe.

We have to watch very carefully that we do not deplete these countries. Because some of them (Poland, the Czech Republic, Hungary) told me, “We hope you won’t do it like the Americans are doing it. Most of our young people stay there after their studies and we need them back home. We need them to build up our countries.” With these countries, we enter into agreements where we make sure that the students cannot immediately go on in their studies, but have to return to their home institution to get their degree. We even help them to build up their own research strength at the home institution, because we feel that otherwise we may jeopardize our future collaboration. Even though we would gain in the short run if we kept these students, we would lose in the long run.

The General Situation in Germany

Unification has cost us a lot. Over the last ten years, the net transfer was about $600 billion. About five percent per annum of our gross domestic product (GDP) went from West Germany to East Germany. This did strain our resources and it was difficult, but I think we have mostly gone through that. Now we will have new opportunities.

What is on the agenda? First, we are seeing a major demographic change in birthrate. Fertile women in Germany, whether German women or women from other countries, have about 1.3 children each. This means that within the next decades, one-third of the German population will be over 60 years of age, and still expecting comfortable pensions. This demographic change is not occurring solely in Germany; it is all over Europe and in many other areas of the world. This is the name of the game for the next decades. To adjust to that will be exceedingly difficult.

The first thing we have to do is to recognize that we always have been an immigration society. Most people do not realize that Germany has, after World War II, absorbed approximately 20 million people. About one-quarter of our population presently in Germany was not born in

Germany. We have integrated 12 million refugees, many coming from the states of the former Soviet Union.

We have gained a lot from the immigrants, but we were not prepared to acknowledge it. We needed them, but we did not acknowledge that they were citizens with us. Now, we have learned better. The need drives us to this realization, and we will have to draw the necessary legal, social and psychological consequences from this fact.

The United States has lived off of the talent of the world in its science system for a long time. We all know what it looks like when you enter engineering or science departments in some of America's best schools. Not too many of the people getting their degrees there were actually born in the United States. This is a situation we have to emulate. We have to learn from you how to attract the very best students to our own universities.

Graduate education was one of the wonderful contributions given to the world by the American educational system. The research university was a German contribution, as most say, but that happened 200 years ago. We have never done so well with graduate schools. We learn from the United States, and I think we should work together to improve our graduate education.

The second point on our agenda is very important for the future. We have to completely reform our educational system, from lower schools to the university system. Many of the old German ways just do not work anymore. We have to reemphasize science and mathematics in the schools. We followed America's lead in the 1960s and 1970s, and introduced curricular reform in which we dismantled a highly successful educational system—the German gymnasium. In this system, every student had enough mathematics and natural sciences to enroll in any subject in a university he or she wanted to. But, we said, "This is not modern. Let them choose the subjects in high school." Well, they chose, but they mostly did not choose math and natural sciences. And if you do not choose these subjects in school, you are not particularly inclined to select one of these subjects as a major in college or in university training. We have to do something about that, and we will.

We also soon hope to get rid of the old German academic career system where habilitation, a formal postdoctoral qualification, played an important role in becoming a university professor. We will let younger scientists come into positions of independence much earlier, at least in the natural sciences. In engineering, habilitation has never been a prerequisite in order to become a professor. In the humanities, in legal studies, and so on, it takes longer. It is more difficult to change ways there. But you will see the German university change with new legal requirements, quite decisively over the next five or ten years.

We do have other shortcomings still. German universities may not select their students. Universities in Germany are, together with the penitentiary system and the military system (at least under compulsory conscription), almost the only other institutions that get their clients assigned. They do not select them; they receive them. We have to change that, but this is against the grain of the egalitarian assumption in the German educational system. This assumption says that all institutions are equal, so we distribute the students. Since they are equal, it does not matter whether you go to Munich or to Göttingen or Heidelberg. There may have been times when this was true, but it is true no longer. We have to change that. We have to learn how to handle tuition systems too, so that the universities feel more responsible for the students, because tuition comes from the students. Presently, the universities get their money from the state, so a student can be more a load than an asset sometimes. This has to change, and it has changed in many places already.

The Science Budget in Germany

Germany is far behind the United States in the percentage of the GDP spent on R&D. It is approximately 2.4 percent now, but increasing (slowly) again after the first ten years since unification. It is approximately $50 billion, with about two-thirds from the private sector and one-third from the public side. We could use more, and we will get more when the tax reforms that have been enacted come into place. But we are too slow in social reforms, pension system reforms, and working relations reforms. A social democratic government, as we have, may find it difficult to make the necessary adjustments in the social relations and security systems. But we will get it done.

Our politicians are well aware of the importance of the innovative sector of science and technology. Our budget for S&T is actually better per capita than that of the United States, if you look at only the non-defense, non-NIH budget.

European Unification

The European Union tries to become a decisive leader as far as the economy and trade in Europe is concerned. But as far as science is concerned, different member states perform on different levels. For example, science in Brussels commands for the whole European Union, less than five percent of the available resources. That may make decision-makers in the United States say that they want to deal with London, or Berlin, or Rome, or Paris, but not with Brussels. We hope this will change.

There is a movement in the direction of a more focused, less bureaucratic concentration on larger projects of added European value, projects no single member state could tackle. Together we can make real progress, and we are working for that.

We are finally beginning to set common priorities and define common centers of excellence in Europe. These centers will be involved in training a pool of young European researchers who will not define themselves as Germans or Italians or Belgians, but as members of the European community, as Europeans. We still have a long way to go, but we are moving in the right direction.

It is important that we have a way to convey a message of enthusiasm to the young European generation. We have to engage them in the excitement of scientific research. We have to make them enthusiastic. But, we may lose the enthusiasm of these young people if they are not inclined to learn to do scientific research. We should not wonder when they all become business analysts, lawyers, etc., and do not select subjects from the sciences or from engineering. We must draw them in.

Future Opportunities for Collaborations between the European and U.S. R&D Systems

What Germany has achieved after the Second World War would not have been possible without the help we received. The achievements of Europe as a whole would not have been possible without the collaboration and the openness that all of us have found in the best of America's institutions. The United States gained a lot also, of course, from being so open.

Scientific development is the most grandiose non-zero sum game in human history. It has helped us come forward in the developed world, and we hope this progress will expand to the developing world in the next decades. We have to do this through collaboration, while at the same time, being highly competitive. This combination of competition and collaboration is the decisive message we can take from the last 50 years.

This is the reason why many of us in Europe, especially from the scientific field, are so deeply disappointed about the recent Kyoto decision made by the U.S. government. We do not think Kyoto is the only solution, however. In fact, Germany (as many other countries) did not meet the goals and will not be able to meet them, even though we meet them better than some others. But it was at least a step in the right direction. The Kyoto Protocol would help all of us determine a concerted action for problems that we have to solve together. To get a message of non-collaboration from a country that holds approximately four percent of the world's population but produces 20 to 25 percent of greenhouse gas emissions is a blow indeed. The United States sent the message that they do not want to take part in this concerted action; this was highly disappointing.

I hear about the terrible fate of having to pay $2.00 a gallon for gasoline in Chicago. Europeans pay $5.00 a gallon, and we are not living in dismal poverty. We hear that we failed to develop new technology, yet we produce the most energy-efficient cars in the world, and sell them at a profit. We do the same with gas turbines, and even renovated our energy production along these lines. We partially lead the world in preparing for hydrogen technology and using fuel cells and many other things in this respect. We lead in exports and in gaining money in environmental technology of the highest quality. Our drivers, including myself, have fits when we pay our gasoline bill. Of course we do, but we realize that this price rise means that we had not so much aim for conservation only. This is actually not the real goal for tomorrow's world. Aim for energy efficiency: this is the real goal, with new technology, better technology.

Together we have to invest in new technology that will be more energy efficient. Together we have to aim for a sustainable world. We do not believe that one country, even if it is the largest country, the leading country, and the only remaining superpower, can do it on its own. As Benjamin Franklin said, "We must all hang together, or assuredly we shall all hang separately."

Germany alone can do almost nothing of global importance, nor can the European Union. But this is also true for the United States, even with all its superpower qualities and amazing economic prowess. I am the first to appreciate these qualities, envy them, and congratulate the

United States on them. In order to get to that level though, the United States has relied, for decades, on a sizeable fraction of the most highly qualified people of the world. The message is that we have to work together. We have to do it together. We have to have global collaboration for science. We must demonstrate to the politicians of all the countries that we know how to serve them well in that respect, and they should solve their problems so we can do our work. The Internet is there for us to use, and approximate English is there for us to use. We have the tools, and the determination. We need the support. And we need to do it together.

The needs are there, the tools are there, so why should we not do it?

36 Science for Society

Lewis M. Branscomb, Gerald Holton, and Gerhard Sonnert

The Concept

The Power of Science and Its Uses

A profound paradox of power and impotence, crying out for a solution, now faces concerned people in every society. On the one hand, there is the unmatched power of basic scientific[1] and technological research, reporting one remarkable advance after another at dizzying speed. On the other hand, individuals and whole societies are plagued by ominous problems that yield all-too-slowly, in part because of persistent ignorance at the fundamental level.

To illustrate: On one side, through astronomical observations and the application of relativity and quantum theory, astrophysicists have been able to describe, in a remarkably quantitative way, the events that are considered to have led to the creation of the universe. Physicists believe they are at the verge of being able to collide the nuclei of heavy atoms into one another at such high energies that the material created in the collision will resemble the stuff from which the entire universe we know exploded in the primordial "big bang." Biologists are now able to map the complex structure of the genome and are on the path to understanding the keys to our personal inheritance and the very mechanisms by

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which living things operate. These are examples of the extraordinary achievements of the human mind, driven chiefly by curiosity, often in an "Ivory Tower," enabling modern humans to understand in extraordinary detail much about life, nature, and how it all began—and on occasion leading (though usually on a long-range time scale) to valuable spin-off opportunities.

On the other side, there are urgent problems where basic science has not been deployed with the necessary level of dedication, such as reducing national dependence on imported energy, and reducing the threat of global climate change from the growing use of fossil fuels. To be sure, *applied* research helps, but typically it uses existing sciences and technologies and thus remains often unable to create the fundamentally new sciences or technologies that are necessary for decisive breakthroughs benefiting our economy and our comforts. For example, the U.S. Department of Energy spends many billions each year on nuclear stockpile stewardship and on environmental remediation of contaminated sites. But it has not been able to dedicate sufficient scientific talent to a long-range and well-endowed program of increasing the efficiency of energy use, and finding new, sustainable sources of power that are environmentally more acceptable. Similar analyses might be applied to many other problem areas in which a long-range commitment of our best basic science would make the problems easier to address with the tools of applied research and development.

If more good minds and sufficient funds were available, could some part of basic scientific research contribute more to the achievement of public objectives than it does today? Can it help to solve our most urgent social problems more directly than now? In short, can we construct a sturdier bridge from the "Ivory Tower" to the sufferings of most of humanity? A positive answer would contribute to solving the painful paradox mentioned at the outset. Our answer, based on historic and recent evidence, is a confident Yes.

An expanded national investment in basic research guided only by intellectual priorities will, as it has in the past, provide many answers that will help advance progress in important national priorities. Continued expansion of this "Newtonian" science is essential. But we take the argument one step farther. A strategic investment in a part of basic research that is clearly designated to address specific national objectives can be expected to make an ever-greater contribution, especially if resources are allocated in pursuit of a well-considered, multi-year strategy.

One kind of evidence for our optimism is the well-known case where public concerns about disease and public health are being addressed by massive investments in publicly funded long-range research. The National Institutes of Health have been extraordinarily successful in showing—and thus convincing the public and their representatives in Congress—that basic studies in molecular and cellular biology are effective strategies in the eventual conquest of disease. This case offers a living demonstration of the power of strategic investments in basic science and basic technology to open new doors to solving the most difficult problems afflicting individuals and society. Equally important, scientific research can inform choices in public policy, so that problems are correctly understood and resources are used in the most effective way.

We also base our confidence on the prior successful federal efforts in our nation's history in fields other than medicine to adopt high-level basic research strategies in service of politically supported goals. Gerhard Sonnert and Harvey Brooks discuss a number of these in the appended paper. One of these, which is discussed in much greater length in a forthcoming book by Sonnert and Gerald Holton[2], was a request President Carter made of Cabinet officers to provide Frank Press, then director of the Office of Science and Technology Policy, with an agenda of basic research goals which they believed would contribute importantly to their departmental or agency missions. This promising initiative culminated in a master list of about 80 basic research questions. Other examples of efforts in the same direction were some of the basic research programs supported by the Department of Agriculture and the Defense Advanced Research Projects Agency (DARPA).

A third source of evidence, of which this Report is a direct product, comes from a two-year examination of the concept and feasibility of giving explicit and conscious attention to a component of science policy, which we have called (for reasons given below) Jeffersonian. This process included a number of meetings with key stakeholders, and culminated in a Conference on Basic Science in the Service of Public Objectives, held in Washington, DC, in November 2000. This forum provided an opportunity for senior scientists and academics, agency leaders, executive branch personnel, politicians and congressional staffers to vet key aspects of a Jeffersonian strategy, and to provide the insights and case discussions found below.

A caveat: We hasten to acknowledge that it would of course be entirely unreasonable to expect basic research to enable significant advances in every problem of importance to the nation. In some cases understanding a problem does not necessarily mean one can find effective, affordable remedies. The remedies that research may allow us to understand depend not only on the conversion of scientific knowledge into practical tools but also on the ability of society's institutions to use these tools and demand more of them. Prevailing social and political conditions influence whether or not available basic and applied knowledge is actually implemented. For example, later in this report we discuss the problem of learning and public education. There has been dramatic progress in research on how people learn, based on progress in cognitive, neurological and behavioral science. But the translation of the basic understanding of learning into how to teach 30 students in a particular classroom lags far behind, in large part because the complex problems of our schools, and of those beyond school, in the lives of students, teachers and parents, inhibit the institutionalization of those particular research findings.

But with this caveat, there is enormous room for a reasonable expectation of positive results from the wider adoption of the research strategy we shall now describe. Indeed, we want to bring to consciousness the opportunity of government agencies to take more responsibility for devising a long-range basic research agenda, in consultation with the scientific community as well as other stakeholders, and for committing the funding to pursue it—along with, and not at the cost of, either appropriate R&D projects for near-term progress on specific problems, or of basic research that aims primarily to sustain the progress of science broadly.

The Concept of Use-Inspired Basic Research, or "Jeffersonian Science"

The introductory quote from the Congressional study led by Congressman Vernon Ehlers (R-MI) clearly speaks to the research policy our society should pursue more aggressively: a governmental commitment to "a pre-eminent position in science and technology to advance human understanding of the universe and all it contains, and to improve the lives, health and freedoms of all peoples." These two motivations for public investment in research address both the cultural and the utilitarian justifications for public support for science. When pursued under the first motivation, in the most creative environments by talented people, this research might be called "basic," "fundamental" or "creative"—or Newtonian science. When pursued under the second motivation, through the application of already known science to problems on a short-term basis, this research may be called "applied"—or Baconian science.

When both motivations are present, it can be identified as "use-inspired basic research," after Stokes[3], or Jeffersonian science, after Holton and Sonnert.[4] As Lewis Branscomb has pointed out, two (related) distinctions are crucial: First, one must distinguish between the motivations of the research sponsor and of the researcher. Second, one must differentiate between the *why* and the *how* of research. Basic research can be described as a venture into the unknown, as an exploration of some of the secrets of our natural and social universe, guided by the researcher's creativity and ingenuity, and by the scientific method. Once this research process has been initiated, it is of little importance whether the motivation behind it was purely curiosity-driven (Newtonian) or triggered by the hope for eventual societal benefits (Jeffersonian).

While some may consider the label Jeffersonian science not fully appropriate for political and bureaucratic use, it nevertheless is convenient shorthand for policy scholars, and is reflective of Jefferson's personal commitment to basic science as a tool for public problem solving. The adjectival structure of Jeffersonian science suggests that an important component of the motivation for pursuing such a research program is different in nature from the motivation in other essential forms of basic research (such as Newtonian science, where the investment is motivated by the quest for scientific excellence and opportunity regardless of eventual societal uses). The Jeffersonian researcher conducts basic research in areas that do have a reasonable chance, in about five to ten years, to ameliorate the scientific ignorance that lies at the heart of a perceived societal problem. This choice also may be made by the research manager in his/her institution, or by the funding agency.[5]

The level of creativity and imagination that propels the research itself need not be different in Jeffersonian and Newtonian science, even if the motives for investing in them are. Jeffersonian science is simply a differently motivated way of selecting a basic research problem, and an additional way of legitimizing the funding of science, not a different way of performing it.[6] Speaking at the November 2000 Conference, Dr. Richard Klausner, director of the National Cancer Institute (NCI), found also that President Jefferson's plan for the Lewis and Clark expedition, with its twin goals of gaining basic knowledge and preparing for the needs of the expanding population, provides a strong metaphor for the exploration and discovery model used in the NCI.

In the interest of not being misunderstood on a crucial point, we want to re-emphasize that we do not claim to have invented a new way of doing research.[7] The historical examples cited above and in the rest of this Report show that Jeffersonian research has long existed, but it requires the visibility and conceptualization that it has not received so far, either in the way the public thinks about the issue, or even in the consciousness of many scientists. Furthermore, we do not advocate that Jeffersonian research should replace basic research—or applied research, with which it is allied—within federal science policy. Rather, we argue that the explicit and conscious attention to Jeffersonian research as part of an integrated federal science policy will benefit all kinds of research—Newtonian, Baconian, and Jeffersonian. From every perspective, ranging from the purely cultural role of science to national preparedness, even the "purest" scientists, for instance, can properly claim their share of the total support given to basic science. But that total sum can more easily be enlarged by the public perception of what basic research can do for the needs of mankind. Even abstract-minded high-energy physicists have learned the hard way that their funding depends on a generally favorable attitude to science as a whole. Moreover, they too can be proud of the use of the campus cyclotron for cancer treatment and the production of radioisotopes, the use of nuclear magnetic resonance (NMR) or synchrocyclotrons for imaging, etc.

Organization of the Blueprint

This Report calls attention to a national opportunity, not yet fully seized, to couple the extraordinary creative power of American science to some of the most intractable problems facing society. It explores, through discussion of two existing models and three case examples, the opportunities available to the nation, the processes of governance required for their attainment, the role of the scientific community in that attainment, and the necessity for engaging public communities outside science. The cases involve using creative, imaginative science to make it easier to attain important public goals in health, environment, energy, and education.

After presenting a detailed discussion of two existing models (the National Cancer Institute and the National Science Foundation) and three test cases, this Report outlines the three major components of an emerging Jeffersonian Science Policy:

- Devising the Agenda—Publics and Policy: To engage a broad range of interested parties—a diverse community of scientists, other stakeholders committed to solution of public challenges, many Congressional committees, executive agencies, industrial and not-for-profit institutions, policy research and advocacy institutions in 'ownership' of the idea, and to define next steps that might be taken by these bodies on the path toward creating a Jeffersonian Agenda.

- Implementing the Agenda—Government Processes: To explore how this idea can be made a practical part of budget-making and program management of an expanding component of federally sponsored research, including the need for coordinated strategies across executive agencies and Congressional commitment to long-range research strategies in pursuit of national objectives, and to the stable support necessary for such strategies.

- Enabling the Agenda—The Scientific Community: To find equally effective means for defending the essential base of opportunistic research whose priorities are guided only by their intrinsic scientific merit (Newtonian science); and to demonstrate, as Maxine Singer noted at the conference, that science must be seen as a ecological system, with interdependencies between ideas and skills, between science and technology, and recognition of a broad range of motivations for investment by government and for performance of research by scientists and engineers. The overall goal is a balanced federal science portfolio of Newtonian, Baconian, and Jeffersonian elements.

Existing Models of Jeffersonian-style Research

The National Cancer Institute (NCI)

Cancer is the second leading cause of death in the United States after heart disease, and most of its forms lead to a protracted illness which just a few decades ago was assumed to be incurable. Over half a million Americans die of cancer each year. There are few public objectives to which science might contribute more compelling than the "war on cancer" launched by President Nixon on January 22, 1971.

Incidents of new cancers as well as deaths from all cancers declined slightly, between 1990 and 1997, despite the growth of population in the U.S. Several relatively rare forms of cancer are now subject to effective treatments. And lung cancer driven by smoking, created a rising tide of deaths that has only begun to abate with the decrease in cigarette consumption. But the National Cancer Institute (NCI) has spent $29 billion. Why has there not been more progress?

The reason this problem is so intractable is that cancer is a collective term for over 100 diseases; the biology of cancer is extraordinarily complex. Most important, back in 1971, when the "War on Cancer" was launched, oncology was a relatively new, low-prestige discipline. NIH, in creating the cancer institute, launched a basic scientific attack on the ignorance of cancer cell behavior. The key is molecular genetics, the science that tells us how cells mutate and how the body recognizes those with genetic mistakes that cause uncontrolled growth.

Creating the extraordinary body of scientific knowledge of immunology, genetics and cell biology required the creation of entire new fields of science. But it is the only strategy that gives hope of understanding how and why cancers happen and how their growth might be inhibited. "We haven't reached where we would like to be in cancer—not because of misplaced strategies, not because of ill-conceived policies—but because cancer is extraordinarily complex," said Richard Klausner, director of NCI. Overcoming cancer, he said, requires basic research as well as appropriate public policies to take advantage of what is learned.[8] This is a Jeffersonian science strategy, investing in the underlying science to reduce the ignorance that stands in the way of progress toward cancer prevention and cure.

How does the NCI present this strategy to an impatient Congress and public? The first sentence of the published *Budget and Program Plan for the National Cancer Institute for FY 2002* reads: "The National Cancer Institute's goal is to stimulate and support scientific discovery and its application to achieve a future when all cancers are uncommon and easily treated." This sentence states that the NCI's goal is attainable and qualitative: A future in which cancer is no longer the terrible specter of disease that haunts is all today. How is that future to be achieved? Through scientific discovery and its application, making NCI neither a purely research agency nor a clinical medical delivery agency. The word "discovery," rather than "research," suggests research with outputs that are applicable to clinical investigation and practice. Who will make these discoveries? Scientists and doctors supported by the NCI and privately supported scientists whose work is stimulated by NCI activities, thus including the outside world, not just NIH scientists and grantees.

Richard Klausner addressed the challenge of executing a Jeffersonian strategy at the November 2000 conference. He described the planning process at NCI as aimed at getting support for a science approach to NCI missions, noting that the "setting of priorities offers an opportunity to defend the Jeffersonian model. One section of the NCI budget document deals with tools, the other with domains of exploration. They are justified by scientific achievements in a previous period. The third component is disease specific. Progress review groups engage in a 9–12 month process of setting priorities for *what we need to know and know how to do* for each disease. The melding of these three things gets agreement on how the first two parts map to the Baconian [practical] needs of the disease perspectives. So scientific opportunity can be made consistent with medical needs. Planning and evaluation must be melded together."

In articulating this strategy we noted that NCI uses the words "exploration and discovery" (rather than "research") as characteristic of the kind of technical activities that are likely to bring public benefit. He observed, "We can plan exploration, but we can't plan discovery. Exploration requires tools, data etc. Tools have been too much ignored. Science is too much seen as hypothesis, but tools enable science and science enables tool building. This is broadly understood by the public and reinforces the requirements for exploration." This choice of language may be important to the image NCI conveys to lay audiences. The public often sees "research" and "science" as arcane activities with both positive and negative impacts on society. Exploration is an adventure with either null or positive results, and discovery is almost always seen as a positive addition to human knowledge.[9]

The specific articulation of a societal need as a challenge requiring new knowledge requires that five issues be addressed in the agency's planning:

1. Articulate the societal need as a challenge requiring new knowledge.
2. Articulate science as the discovery process that will create that knowledge.
3. Articulate the connection between discovery and the application of discovery to the societal need.
4. Establish criteria for determining the vehicles and support needs for the explorations required.
5. Address with realism the timelines (5–7 years) and the uncertainties of both timelines and plans that are fundamentally dependent on what is discovered.

Klausner also noted that industry plays an important role in their strategy and in garnering support for it. He also notes that once one commits to society's enjoyment of beneficial outcomes from discovery, one must engage the social sciences as well. In fact, he said the social sciences are the NCI's most rapid growing area of science investment.

In using NCI as a possible model for Jeffersonian science, we are not asserting that the model has been validated by objective analysis of the causal and cost-effective linkage between NCI research and the ravages of cancer in the U.S. population. But there can hardly be debate over whether the model has won the support of almost all the groups committed to the fight against cancer: the public support groups, the biomedical research community and most oncology specialists.

The NIH model for funding scientific research contains underlying factors specific to the medical field, and has developed over a long period of time. Nonetheless, as Donald Stokes points out in *Pasteur's Quadrant*, "it is…unreasonable to think that only biomedical research lends itself to the virtues of the NIH model of a scientific agency focused on an area of recognized social need that is able to enlist basic science of the highest caliber from a range of disciplines to develop a fundamental understanding of the phenomena that underlie the problem area, while it also sponsors some pure research and some purely applied research."

The National Science Foundation's Approach to Basic Research in Support of National Goals

"Enabling the nation's future through discovery, learning and innovation," director Rita Colwell's vision for the National Science Foundation (NSF), also comports to the principles in the NCI mission statement. She emphasizes enabling (rather than causing or managing) the future as the goal, and discovery, learning and innovation as the means. "Including innovation reveals our commitment to the public. We strive to move society to a better place." She further said, "The objective of connecting discovery to society is central to our work." Thus the question Walter Massey, then NSF director, put to his NSB Commission on the Future of NSF, in 1992, has now been answered in the affirmative.[10] NSF does accept responsibility for understanding and fostering the chain of events through which the research it supports creates positive outcomes for society.

Like NCI, the NSF strategic goals now encompass people, ideas, and tools. The concept of "people" embraces not only the basic mission in science and engineering education—furthered at the university level primarily through support of graduate student research and fellowships—but also the importance of dialog with the American public. NSF reaches some 50 million people through museums and another 100 million through radio, television, and film, although these activities are managed as "public understanding of science" rather than as part of structured strategies tied to specific goals. Like the NCI, NSF's emphasis on tools—the telescopes, ships and databases constituting the infrastructure of modern science—is consistent with the concept of enabling the future.

The emphasis on knowledge production is reflected both in disciplinary research selected by peer review from the ideas of individual scientists (Newtonian science), and in the initiatives which emphasize the opportunities for interdisciplinary research motivated by understandable national objectives (Jeffersonian science). NSF has mapped new initiatives into FY 2002 (Mathematics) and FY 2003 (Social Behavioral and Economic Sciences). These initiatives, Dr. Colwell said, will "enable NSF to center attention on national and global priorities." "Each of these initiatives cuts across traditional disciplines to bring a broad spectrum of resources to bear on areas of national importance. These areas are self evident."

Dr. Colwell noted that "today we are looking at a total U.S. economy in the order of $10.4 trillion, yet our estimate is that the United States government spends barely $20 billion on basic research. Using these numbers as a guide, we see that (federally supported) basic research efforts constitute 0.2 percent of the overall economy. That is the government's investment in the country's future. Out of the $1.9 trillion federal government budget, basic research constitutes 1.1 percent of the total budget. With this meager amount of federal investment, enormous forces tug at the NSF purse strings. NSF is required to make tough decisions, with the inevitable result that people and discoveries are lost in the process."

Some conferees in the November 2000 meeting pointed to differences in the NSF and NIH approaches, suggesting that NSF might take the concept further. For example, one observed that the process described by the NCI is more than 'talking about science with the public'. NCI has set up a way of listening to different constituencies, and educating them about NIH process, goals, and ways of choosing projects, as well as engaging them in discussions about program priorities. The same cannot yet be said about NSF's approach. In fact, education and education research could be used by NSF to move in the direction of NIH's interaction with the public.

Three Cases for Exploring Jeffersonian Science

From the three case discussions explored in the November 2000 conference, to which we now turn, we wanted to learn the following:

- Can one select some examples that give us confidence in the value of trying to get a stronger commitment to multi-year explorations that make progress toward a national objective quicker, cheaper, better?

- Are there common features to the processes required to gain consensus support behind such a strategy?

It should be stressed that the choice of issues for the case discussions in no way represents an attempt to preempt the public and political discussions through which national priorities are set, a process to which we dedicate a great deal of discussion below. Rather the issues of education, energy and climate change are currently generating significant attention in the country, and thus lend themselves to as cases to explore the possibilities of Jeffersonian strategies.

Improving the Quality and Efficiency of Public Education

Education cries out for new approaches using existing and potential results of research, but the return on that research is seriously frustrated by lack of demand from the educational institutions. The case of education raises three key problems that Jeffersonian research can address: Does research on how people learn and how schools can be more effective exist that, if widely adopted, would permit broad and rapid progress toward an acceptable performance of the nation's schools? If so, what barriers must be lowered to permit a long-range learning and education research strategy to add value? Can demand be created for the needed research?

In the National Research Council (NRC) book entitled *How People Learn: Brain, Mind, Experience and School,*[10] the authors discuss the "convergence of evidence from a number of scientific fields," noting that "the research areas relevant to the science of learning are demonstratively broad, including cognitive development, cognitive science, developmental psychology, neuroscience, anthropology, social psychology, sociology, cross-cultural research, research on learning in subject areas such as science, mathematics, history, and research on effective teaching, pedagogy, and the design of learning environments. New technologies for assessing learning in ways that track the growth of learning, not just cumulative of facts, are needed. Developing effective research methodologies is particularly important for research from this diverse array of disciplines."[11]

At the Conference, John Bransford of Vanderbilt University asserted that current research has produced four requirements for effective education that are well known and verified by research:

a. Students must master substantive content knowledge; problem solving must be based on content mastery.
b. Teachers must also have pedagogical knowledge: Understanding struggles of novices in acquiring content knowledge is important.
c. Teacher quality and capability are essential.
d. Teaching for understanding and not just memory is necessary.

How can one get a cumulative knowledge base on thinking and learning, and make it accessible to practitioners? We need new avenues for capturing the wisdom of practice, and we need a new kind of professional who can bridge the worlds of research and practice.

Alexandra Wigdor defined the issues that control whether demand can be created for this research:

a. How can learning/cognition be incorporated into practice?
b. How to make research on motivation meet classroom needs?
c. How to make school environment support learning?
d. How to make research findings more accessible?
e. Need new forms of collaboration based on teacher/school demand.
f. Creating new instruments for expressing demand—such as National Board for Professional Teaching Standards.

Dr. Nora Sabelli, addressing the question of why research is not used in practice, noted that teachers don't have the time that would be needed to synthesize research, nor the schools have an ethos of experimentation that supports adapting research generated knowledge to local conditions, and that there is a lack of funds for long-term projects to integrate the research knowledge into localized practice. Similarly, there is a lack of infrastructure support that enables this integration of research with practice in effective ways. Sources of this type of funding for research are relatively scarce, and thus no research capacity has evolved at the intermediate (state, metropolitan area) levels, and no or very little private sector research exists on education. There is also the constant issue of public perceptions of education, where the belief that teaching and learning abilities are innate, not subject to development and change, or alternatively that education (and social science) research is no better than common sense, stand in the way of validated, evolutionary improvements in practice.

It can be argued that NIH's success has shifted the balance between medical research and public health research (note, though, that NIH is actively increasing its reliance on social sciences). To avoid a similar imbalance between Newtonian, Jeffersonian and Baconian research in education, other agencies besides NIH and NSF—such as the Department of Education and the States—would have to have the resources to take up the public engagement aspects of education research implementation.

A conclusion concurred in by Bransford, Wigdor and Sabelli, and strongly supported by Maxine Singer:

> Until the business community recognizes the huge size of this market and devises a way to overcome the fragmentation of its demand structure, it is unlikely that there will be an aggregation of demand that can truly benefit from research. This commercial linkage is clearly a key part of the success of NIH and in its defense of linking science to practice.[12]

David Guston noted that the states have dealt effectively with the transfer of research knowledge to practice in agriculture, where the aggregation of the market is a consequence of the commodity nature of the product. Education looks more like the problem of small manufacturer innovation, where each small firm conceives of itself as having unique problems calling for unique solutions. Nevertheless, Lewis Branscomb suggested that the agricultural model might be applicable in two of its features: a politically acceptable role for federal agencies in support of research and identification of best practices, and the concept of extension agents, with the resources and authority of state education agencies behind them, working directly with the schools.

Sustainable, Environmentally Acceptable Sources of Energy

Energy would appear to be the most natural case for a long-range basic research program to create new energy options, but is inhibited by traditional structures in Congress and in the Department of Energy (DOE), and perhaps by the presence of a private sector too heavily invested in current sources and uses of energy, responding to markets that do not reflect future costs.

John Holdren made the case that the strategy to address the U.S. energy problem is to generate better energy options: higher efficiency fossil and biomass fuels, solar photovoltaic, more efficient energy usage, more acceptable sources of fission energy, and other more "long shot" technological alternatives to fossil fuels. The case for giving high priority to energy research is clear: energy R&D declined 3.8 fold from FY 78 to FY 97, due to a return to low gas prices, the failure of demonstration projects, budget constraints in Congress, and some political infighting among energy options. Private sector investment in energy R&D also declined some 40 percent, but far less than public sector investment. Yet energy has many externalities that require comprehensive solutions, such as the increased likelihood of conflict over oil resources in the Middle East, the necessity of changing energy modes to mitigate accelerating climate change, and the cost of controlling air pollution.

Thus energy would appear to be an ideal candidate for a long-range research program devoted to the creation of new technical options. There is a major industrial market for such technology, and relatively few non-market barriers (except for nuclear energy). Yet such a program has yet to mature in the Department of Energy.

To understand this apparent anomaly, consider that energy activities are only $2.2 billion out $18.8 billion in the DOE budget. The DOE Office of Science, has a budget of about $1.5 billion. Mildred Dresselhaus, the former head of the Office of Science, stated that she felt that her job was to make U.S. a leader in physical science and engineering again. This is an admirable goal, given the failure of the Department of Defense (DoD) to keep up funding in those areas, while NIH budgets soared. But it appears that creating a long-range, diversified research strategy to create new energy technology alternatives is not the dominant priority of the Office or of the Department. At the same time, the Department's recently released energy R&D strategy seemed to be quite clear in its Baconian thrusts. What seemed missing is the Jeffersonian strategy.

One possible explanation (aside from the often expressed view that the DOE is not as well managed as it might be) is that in this field, unlike in education, the government, which regulates the energy sector in many ways, has failed to find a mode of collaboration sufficiently attractive to industry to produce the needed demand for government sponsored basic research.

Former associate director of OMB for energy, natural resources and science, Elgie Holstein, observed that all technologies have powerful constituencies. Questions such as "Are fossil fuels yesterday's news or the basis for a better future?" "Should we be spending money on clean coal technology?" "Should we bet on certain non-fossil fuel technologies? windmills? nuclear?" contend for answers. Note that the NIH has an analogous problem, because each disease has its dedicated advocates, but there is a difference. The economic interests in health are not organized by disease, but rather by what they provide—hospital care, pharmaceuticals, and medical equipment. Thus each economic sector has an interest in all the diseases. In energy the industries tend to be technology specific. As Holstein concluded, "From the perspective of OMB, one is balancing between strategic investments and demands of competing claimants."

David Garman, a 20-year Hill veteran who has worked for key Energy Committee and subcommittee chairmen, observed that the members of Congress for whom he works would generally agree with Holdren's recommendations. So why hasn't Congress been more generous? There are structural impediments, such as the fact that committee jurisdictions are split for energy, environment and energy science research. The energy committee sees itself as booster of energy production; the environment committee sees itself as an energy regulator; the science committee has not paid much attention to energy issues outside of climate change. There is also the problem of political support for such research. Typically, the U.S. public wants to spend on energy only when there is a national emergency. The public understands cancer risk and supports biomedical research. Does it equally well understand the risks associated with climate change, air pollution, and import dependency?

Global Climate Change

Climate research seems a natural case, and the scientific leadership has correctly chosen regional mitigation as the research focus, thus meeting both key research issues and creating a more attractive and viable basis for a bipartisan research program of appropriate magnitude.

William Clark outlined the revolution in thinking about global climate change, since research began back in the International Geophysical Year (1957). Vostok ice cores showed history was chaotic; our theories did not embrace the cross coupling of geophysical and biological systems, and had no knowledge of human activity intrusion on nature (now known to be comparable to natural cycles). Roger Revelle saw that our use of fossil fuels was a great geophysical experiment. ("We may be in the test tube—we may *be* the test tube."—Jane Lubchenko)

Policy-driven, method-driven, and curiosity-driven research motives have merged. In the 1990s scientists found their research more and more driven by policy considerations, but thought their research was being distorted by the "problem of the week." The Global Environment Change program was created by scientists to get some stability against the "problem of the week" (more in Europe than in the U.S.). This morphed into a climate change agenda, which resulted in stable research support in earth systems research. Administration, Congress, and science reached agreement to keep the program growing at levels the community said were needed to get ahead of the curve.

Today the scientific community is saying that we have to address the social issues. What is the role of the scientist, for we are part of the transformation that we are also trying to study? Now the social and natural science parts look for an integrated understanding. The social agendas are increasingly the motivation for setting research priorities. For example, scientists have recently completed an analysis of the impact U.S. of climate change in 20 regions.[13] Researchers found that people weren't interested in climate, but in land use and job building, etc. Integrated looks at multiple environmental stresses are needed, not one stress at a time. Research resources for regionally focused research are inadequate. If it is not national and it is not disciplinary, it sounds like "pork."

Warren Washington made the case that, since 1996, a scientific consensus has solidified around the conclusion that human activities are and will be appreciable compared to natural cycles.[14] Data clearly show global temperature rising since mid-1880s, about 0.7 degrees Celsius. Serious research problems remain: climate models have improved, but clouds, aerosols and radiation create the biggest questions. There is high uncertainty about rapid changes in ocean and the sea ice aspects of climate. El Niño and Southern Oscillation are hard to predict but have been strong recently. Heavy and extreme precipitation trend will continue. It is expected that this will cause increased flooding which will be hard to deal with. Also because of increased warm in certain regions there is a strong possibility of increased drought periods.

In last couple of years there has been a positive change in Congressional attitude toward R&D funding: Why? Congressmen believe that science has something to do with the lengthy economic expansion, and they do not want to risk stifling it by cutting funding. Furthermore, the high-tech community has become more politically active, especially in financial support of candidates.

Incrementally reducing scientific uncertainty, as a way to make policy easier, is not the way to sell the program, Robert Palmer, senior staff member of the House Science Committee, said. Members of the committee are more interested in regional livability. Maybe environment can be tied in to these current issues, especially with the emphasis on the importance of regional analysis of climate impacts.

Many scientists imagine what policy makers ought to want to know. That approach does not work. What is required is to understand what knowledge system can connect basic research through assessment to policy and back again. At the regional scale, one can put the users and intermediaries into the process more easily, and that is where the program should be moving. Global Change people should declare victory. The mesoscale problem, El Niño etc., is where the fundamentally exciting research is going on. Mitigation research has the value of presenting society with some tools, with the national climate change trend as motivator, to believe something can be done, so when the case for human-driven exacerbation becomes solid it can be accepted and acted on.

Devising the Agenda: Publics and Policy: Activating Constituencies and Stakeholders for Jeffersonian Research

The Crucial Link: Public Support and Curiosity-Driven Research

One of the most important features of the Jeffersonian approach is the conclusion that stable funding for basic research that supports broad societal goals must rest on a consensus of strong, supportive, public constituencies. This approach explicitly acknowledges that in various segments of the public there is confusion and ambivalence about the mission of research in science and technology. As the National Science Board (NSB) reports in *Science and Engineering Indicators*, the U.S.

population is still highly favorable toward science as a hope for positive results—far more than, say, the Japanese public; but they are no longer satisfied with waiting patiently for the uncertain and unpredictable "spin-offs" with which Vannevar Bush justified federal investment in basic research.

This is in part the scientists' fault for failing to communicate effectively the many ways scientific research creates value and opportunity. Neal Lane recently urged scientists to "let people remember" the impact of science and technology. Some additional efforts have started, such as the National Academy's Office of Public Understanding of Science, the NSF Programs with similar aims, the efforts by professional societies, such as AAAS, APS, ACS, etc. Such efforts are needed and no doubt contribute to public understanding of science. And yet, there is a rising call from the public, reflected by their political representatives, to have scientific research and technology perform more obviously for the public good.

The passage of the Government Performance and Results Act (GPRA) in 1993, reflects just such expectations. The one area of publicly funded scientific research work that seems to satisfy this public expectation is in biomedical research (as reflected in the daily bombardment of news of "breakthroughs" in medicine and biology generally).

The public and the politicians thus remain ambivalent about support for basic research.[15] Among the many symptoms of the present ambivalence, one only has to look at the fact that, according to *Science and Engineering Indicators*, roughly 50 percent of the population believe that sometimes scientists engage in fraud—which coheres with, and is in part driven by, the delegitimization of science coming from sections of the press and polity, where one routinely finds pronouncements such as "Scientists want only a blank check" to further their careers, and from the sections of academe accusing the scientists of "socially constructing" their work in pursuit of their self interest

The public's ambivalence of course is also reflected to some degree by warnings among our lawmakers. Thus Senator Harry Reid (D-NV) warned (April 13, 1999) that many people "seem to see science as a luxury…that can be reduced or abandoned."

The Jeffersonian approach seeks to address this apparent ambivalence in the public support for basic science by crafting strategies that firmly link curiosity-driven research to the goals and concerns of citizens and their political representatives. It harnesses the recognition by many scientists that they are accountable to society for the resources invested in their research, and the conviction that long-term, creative research that creates deeper understandings of problems facing society must be an essential part of a strategy to ameliorate those problems. A Jeffersonian Science Policy will foster new and attractive options for addressing crucial societal goals, and thus decrease the cost and time for making progress while resulting in more favorable outcomes.

Jeffersonian-mode research is, of course, not a new idea, and there is ample evidence to support the notion that a stable, and even expanding base of government financial support can be created through a serious effort to structure fundamental scientific research that is supported by strong public constituencies and stakeholders. At a November 1999, Washington, DC, workshop, which served as a launching point for the current initiative, then-director of the National Institutes of Health, Dr. Harold Varmus, acknowledged that the NIH strategy is essentially Jeffersonian, and that this in part accounts for NIH's success in attracting resources to long-range basic programs. He described four broad elements of that strategy, and the pitfalls it must avoid to be successful.

First, the goal (in this case, to address the major illnesses that plague the citizenry) must be simple, clear and self-evident. The NIH institutes are typically named for the disease that motivates much of their research (Heart, Cancer, etc.) Significantly, the Institute for General Medicine has more difficulty in gaining support than those with disease-related names.[16] At the same time when pressed to pursue a *war on cancer*, a metaphor basically Baconian in style, the response has to be twofold: it should, on the one hand, note that progress has been made on many cancers; and, on the other hand, emphasize the many other medical benefits that NIH's Jeffersonian strategy has also given to the public. Thus the metric by which progress is assessed politically must be broader and more flexible than the shorthand banner under which the program advances.

Second, Varmus called attention to the necessity of active public support for the Jeffersonian goal and strategy through interest groups, which are abundant in medicine. The range of potential advocacy groups covers all the interested groups and institutions: including biomedical industry, "patients," physicians and other health care providers and insurers, research universities, distinguished scientists who themselves are doing purely Newtonian research, and public interest advocacy groups committed to specific elements of the biomedical agenda. The existence of issue-specific public advocacy groups and the goals they adopt for their own interests validate the similar goals adopted by NIH. But these groups must be brought together so that their influence is more supportive rather than fostering competition among "favored" diseases. This is accomplished by means of a large council of citizen groups of which as many as 100 might be represented. In this way, tradeoffs among their competing interests can be subordinated, at least to some extent, to the larger common objective of a larger 'pie' of resources for which to compete.

Third, owing to its focus on health, it is easier for NIH than for other agencies to showcase the link between its basic research and benefits to "user" communities. Varmus pointed out that NIH invests $2 billion in clinical research annually, which allows specific examples of new medical capabilities that embody more basic scientific research to be visible in the evening news.[17] This illustrates that a Jeffersonian strategy can be strengthened if it is complemented by a more Baconian approach to the delivery of outcomes. This also helps the sponsoring agency to satisfy the requirements of the Government Performance and Results Act. As Harvey Brooks noted at the November 1999 workshop, some other agencies can do this, too, pointing to research resulting in the Internet, or to the history of agricultural research (with benefits not only to the nation, but worldwide.)

Finally, Varmus noted that the serious intellectual work of building the right basic research strategy and of constantly revising it as the science and problems change is essential, as is a very active and effective ongoing dialogue with political and public interest groups

Selecting Goals to which Science Can Best Contribute

What are the national purposes to which strategic investments in basic science can most effectively contribute? David Hamburg, in his keynote remarks to the November 2000 conference, identified four groups of goals selected by the 1992 study, led by Guyford Stever, for the Carnegie Corporation's Commission on Science, Technology and Government:

- Quality of life, health and human development
- Sustainable economy
- Environment and natural resources
- Personal, national and international security

A collaboration of public and private efforts is required for progress in all four of these broad goals. Federal agencies are charged with the responsibility for contributing to them. Ultimately the public must set the goals and define its priorities. How is that to be accomplished? Who will set the goals and priorities that determine the allocation of resources for federally funded research?

"Enabling the Future: Linking S&T to National Goals," the title of the Stever report, attempted to answer this question, calling for a National Forum on National Goals. Hamburg noted that scientific bodies such as the National Academies, AAAS, Sigma Xi, or perhaps a new institution, might create the venue for exploring the most promising opportunities for science to contribute to public purposes.

As Maxine Singer points out, defining the public interest is not easy, since both political and scientific inputs are required. The media, she notes, do not do a good job of helping the public understand where science can best contribute. She offered, as a current example, human stem cell research: "Many believe this research is in the public interest, but many Americans reject the idea. Where does the public interest lie? What is the public interest in genetically modified plants? Can anyone say? Some people are concerned about motivation of large corporations, others about organic foods, others about environmental implications, others about international issues. But there is consensus on broad issues: defense (if one is not specific), curing cancer (if you are not talking about stem cells)."

One can imagine a process for selecting public goals and defining the role of Jeffersonian science in addressing them. Suppose focus groups of citizens were asked to make a list of the problems they wanted government to address, listed in order of importance. The list might include curing and preventing disease, finding new, sustainable sources of energy, deterring threats to national security, avoiding the worst consequences of global climate change, improving our schools, achieving social and civil justice. Then imagine that a group of broadly expert researchers were brought in to describe, for each goal, what kind of basic research would be suitable to improve our incomplete understanding of the issues and find new options for dealing with them. A reordered list, according to the combination of how important an issue was thought to be and the likelihood that in time research could make the problem more tractable, would constitute the priority list for public Jeffersonian science investments. In practice, of course, the list of problems is debated every day by politicians who are surrogates for the citizens, and the scientific community struggles to find a way to inject its views on where science can make the most effective contribution into that political discussion.

Three factors make the injection of the scientific view into the lay public's discourse more difficult. First, cynics will say that the equilibrium of political and institutional pressures, not evaluations based on deeper understanding, will determine the priority accorded to public concerns. Second, the scientific community is not in uniform agreement about the efficacy of research in remediation of public concerns. This second factor has two roots: Many of the issues call for applications of the social sciences, with attendant debates about their practical applicability and assertions about their ideological implications. Moreover, there are often serious barriers to the expression of demand for results of social science research and skepticism about its utility, as in the case of public education reform. The third factor arises from the fact that the science research agencies of the federal government, with the exceptions of agriculture and NIH, have little experience in engaging lay publics in dialogue about the contribution of research to public interests. Yet that is just what is required to build the support and ensure the success of Jeffersonian science.

Implementing The Agenda: Developing Government Processes that Effectively Couple Basic Science to Important National Objectives.

The second major component of Jeffersonian Science Policy is to couple public constituencies with mechanisms for implementing policy. The framework for science policy-making in the presence of interest groups and institutions must be addressed. Any alternative policy, such as a Jeffersonian one, must meet the requirements of politics and bureaucracy in order to become a meaningful force within the budgetary process.

Total investment in research and development in the United States reached almost $265 billion in the year 2000, an increase of 60 percent from the level in 1993. But this growth is almost all in the private sector and is development, not basic research. Government support for research and development has shown much less growth (about 11.5 percent) and was less than half of the level of private investment in 2000. Of this only $23 billion was spent by the federal government on basic research in 2000.[18] Because federal agencies provide the primary support for long-range, basic research in our universities and national laboratories, this public support is crucial for both intellectual progress and stimulating more applied activities, mainly in the private sector.

Building Bipartisan Support

A first requirement is that any public expenditure that must be sustained over many years must also enjoy bipartisan support. Thus any formulation of Jeffersonian science must be seen by both parties either as a-political or as of equal value to both parties. David Guston, discussing Representative Ehlers' call for a new science policy at the November 2000 conference, noted that Representative Ehlers moved "politics" into the center of the discussion, because Jeffersonian science may not be as bipartisan as hoped for. It has a more apparent political attraction than Newtonian science; that is, decision makers will understand its consequences for the creation of and impact on organized interests. And it may compete with more applied Baconian science. For example, some activist cancer groups might respond to NCI's commitment to Jeffersonian science by insisting on a higher priority for short term efforts, such as acting on the knowledge of the behavioral and environmental causes of cancer we already possess, not waiting for addressing knowledge gaps in the quest for new scientific discoveries of cancer cures.

Another limitation, noted by former-science advisor Jack Gibbons at the conference, is the limited internal capabilities in the Congress. There are few scientists in Congress. The organization of Congress is highly complex and arbitrary, and many of the important science policy inputs, such as the Office of Technology Assessment and the science division of the Congressional Research Service, are gone. However, the Congress does reflect American optimism about the value of research and exploration. Whereas politicians went through some narrowing of commitment in the middle 1990s, thinking that maybe the private sector might pick up the slack, that tendency is now behind us. Congress is still uneasy, however; federal funds for basic research are perceived as desirable, but given the general impression that beneficial outcomes may be delayed by a decade or more, those research investments lack the urgency to compete with other demands. Is government now increasing expenditures on research that is going farther downstream toward the market, in order to shorten the payback delay? There is unease about this trend too, both regarding inequitable disbursement of funds and uneven geographical distribution of research funding.

In November 1999, then-science advisor Neal Lane made the point that even if currently there appears to be strong support for science in

Congress, this support is not solid, but vulnerable. If questioned by constituents about why tax money should be spent on science, many politicians will have a hard time making the case convincingly. Here it would make a tremendous difference if the executive branch and/or the science community provided the politicians with more cogent and persuasive rationales for governmental science support.

Creating Basic Research Budgets and Presenting them to Congress

Data on federal basic research (and R&D) is packaged for the congress in three versions:

- R&D (president's request FY 2001) $85.4 billion (Including defense development, testing and evaluation)

- Federal Science and Technology (FS&T) $53.7 billion (National Academies and AAAS)

- 21st Century Research Fund: $42.9 billion (OMB, including almost all of Federal basic research, over 30 percent of Federal applied research and about half of Federal non-defense development, know as Federal Science and Technology Budget in FY 2002)

These three versions of the FY 2001 budget for research and development activities represent the various ways in which budgets are tracked, with R&D being the broadest and least detailed approach in terms of isolating the type (basic, applied) of research being funded.

FS&T is an attempt to gather together activities leading to new knowledge and new enabling technologies, with the actual numbers being obtained by subtracting large budget items that appear to create relatively little new technical knowledge, such as DoD field-testing and installation of new technologies.[19] Who reads these numbers in Congress? The appropriating committees originally asked for the report that generated the FS&T reconstruction, but the committees are generally inflexible in terms of their budget structures. If the FS&T analysis from the NRC and AAAS is read at all, it is by authorizing committees.

The Office of Management and Budget (OMB) traditionally tracks R&D broken out by basic research, applied research, and development, as well as by agency. It collects the numbers from the agencies before President's budget goes to Congress and presents an R&D analysis after the fact. For FY 1999 the Administration proposed a "Research Fund for America," intending to use the tobacco settlement money. Renamed the 21st Century Fund the next year, it allowed tracking the research budget both internally and in Congress, week by week, because it was defined in terms of line items in the Federal budget submission to Congress. OMB has begun to use it to address the issue of "balance," and to encourage the interesting things that are happening at the boundaries of disciplines. The 21st Century Fund is comprised of most of the basic research, a third of applied, and half of civilian development from the total R&D budget.[19]

Are agencies consistent in their definitions? OMB defines basic, applied, development, but agencies interpret definitions differently. For example, NIH considers its entire budget some kind of investment, while NSF excludes some of its funding from research and development (staff of NSF, for example, or the logistical support for Antarctic program).

Interagency Coordination of Research Strategies

Classification of science as basic, applied, and development is problematical, not only on theoretical grounds but as an obstacle to sorting out the distinction between the political motivation for investment in research and the conditions under which it is performed.[20] Thus strategic investment in basic research justified by opportunities to make progress toward national goals might be considered by some as "basic" and by others as "applied." This challenge to the way government agencies categorize their research investments is exacerbated by the fact that basic technological research will play an important role in the pursuit of many national goals.[21]

The Office of Science and Technology Policy (OSTP) and OMB, with advice from PCAST, could establish those long-term goals in budgetary form and monitor agency progress toward them. Bromley noted that PCAST could be a significant mechanism for bringing high-level nongovernmental evaluation to these long-range research programs, but this would require a level of time commitment (and budget) more characteristic of PSAC (President's Science Advisory Committee) in the 1960s. As Jack Gibbons stated, the added burden on OSTP to oversee the development of these programs would require, more than ever, an increase in the Congressionally budgeted staff for OSTP.[22] Hamburg suggested that this should be done separately from the annual budget, consistent with Allan Bromley's suggestion—a two-tiered budget process, with a few, multi-year presidential initiatives, plus the regular, evolutionary budget.

Both Bromley and Gibbons saw the White House interagency research agency body—the Federal Coordination Committee on Science and Technology (FCCST) and the National Science and Technology Council (NSTC) respectively—as a useful management vehicle for the required interagency coordination. Bromley, reviewing his experience in the Bush administration, felt that OSTP, OMB, and the agencies, with FCCST, brought about major changes to enable the Jeffersonian research mode. Whichever device is used to formulate interagency programs, and however OSTP and OMB work together to monitor and manage them, a clear requirement is cross-agency coordination of these long-term programs.

A Macro Budget Strategy

The long-term basic research strategies would be established at the level of broad, cross-agency, program objectives. Thus they would form part of the macro-budget strategy. The value of outputs from Jeffersonian strategies would be evaluated at the integrated program level also. Thus when the strategy is being updated, groups of experts would be asked to evaluate what was learned from the totality of the work of the scientific enterprise. But the funds, once allocated to program managers in the agencies, would be distributed under the discipline of peer review, a micro-budget strategy to assure the highest quality in each and every research project. This distinction was clearly seen by Stokes (1997:121). For this reason OSTP and the NSTC (or its equivalent) must play a significant role in strategy setting and evaluation, but individual scientists would not be required to justify their basic research in terms of expected application benefits, whether it were funded under a Jeffersonian or a Newtonian budget allocation. [See A Micro Project Strategy, p. xxx].

Enabling the Agenda: The Scientific Community—Expectations, Motivations and Goals

At a time when a new covenant between science and society is being sought, and when disenchanted or aggressively anti-science forces chip away at the moral authority of science itself, the exhibition of the existence and eventual successful results of the Jeffersonian model should change the general tone in the future. At a lecture at Harvard University, former presidential science advisory Neal Lane described the "science culture barrier…that has to do with our image, the image of the 'white lab coat,' or the 'ivory tower,' or 'cloning ourselves,' or 'curiosity driven,' or 'knowledge for knowledge's sake,' or similar descriptions that are seriously misunderstood."

Lane suggested "the concept of Jeffersonian science can help us develop a strategy for addressing this image problem, but it will take some serious effort on our parts. There are, of course, two aspects to deal with. One is the need for understanding and consensus within the research community that this is the right way to think about science and even to set research priorities, at least at a general level. And, the other is the need for effective communication of these notions. A dialogue is really what we need, with the larger society."

A Micro Project Strategy

While it is essential for the scientific community to do a better job of talking about science with the public, with opinion makers and with politicians, the concept of basic science in service to public objectives does *not* (like the Mansfield amendment) mean that the researchers should be expected to defend the relevance of each specific project to the public objectives it might support. As discussed [in Interagency Coordination of Research Strategy, p. xxx] the responsibility for identifying the national goal by which Jeffersonian science budgets are justified lies with government officials. This forms part of the macro-budget function. Applicants for an NSF grant are, of course, required to defend their proposals. They are asked to indicate how the proposed work will advance scientific understanding and how, also, it might bring value to society and to the institution of science.[23] These responses are an important part of the basis for peer evaluation. Scientists proposing single projects should not be required to describe in detail the public value that justifies the work.[24] They may of course volunteer that information if they wish. The primary job of linking basic science research and public objectives is for the funding agency, for its advisors, and for the lay institutions that identify goals they believe Jeffersonian science should support.

6.2 Human Resources: Equity, Sufficiency and Societal Interests

The issues a Jeffersonian science agenda seeks to address go beyond defining research agendas and specifying conditions for their performance. A basic question must be: "What capabilities does the nation require to address the challenges in our society in the coming century?" This phrasing clearly brings in not only the idea of a broader source of priorities for research investment, but the importance of education reform, of reversing the decline of student interest in science, and of the engagement of more women, minorities and handicapped persons in science—in short the balance of human resources required for a truly healthy scientific enterprise

As noted earlier, the public at large does not feel it has a sufficient stake in the scientific enterprise, particularly its more "ivory tower" parts in which linkage with the ultimate solution of societal problems is somewhat indirect and uncertain. This lack of a perceived stake in scientific and technological progress applies particularly to demographic groups that will form a growing fraction of the U.S. population and voters in the next two decades, if not in the longer-term future.[25] It applies as well to women, who will comprise a growing fraction of the full-time work force, including increasingly its upper echelons.

It has been pointed out that our unprecedented prosperity, largely driven by the explosive growth of the high tech sector, would not have been possible without a flood of immigrants educated abroad, particularly from India and China and other Asian countries. This dependence on foreign labor from mainly developing countries creates a very unstable situation that cannot go on indefinitely.[26] Moreover, it is likely to create a serious backlash if there is even a slight slowdown in the economy, since the number of low-tech and service jobs at the bottom of the social ladder has been steadily shrinking, and most of these jobs have been held by disadvantaged minorities or women. These people are voters and form part of the constituency that needs to be convinced that they have a stake in the economic benefits resulting from science. So far the backlash has been directed mainly at the World Trade Organization and free trade, but it is only a question of time before it is also directed against technology, and, by association, the science on which it is based.

Publicly supported Jeffersonian-type and even Newtonian type research is responsible for uncovering most of the otherwise unforeseen negative impacts of the application of science and technology, both old and new. Some of these adverse impacts fall differentially on the poor and on minorities. Women as a group are often much more concerned with adverse environmental and health impacts than the rest of the population. Jeffersonian science is an important tool for insuring the responsible use of technology, especially when it is developing very rapidly, and this relates directly to public issues in which minorities and women have a big stake. Consequently, it is important that these groups have spokespeople who are technically literate, and it is furthermore important that members of underrepresented groups are visible parts of the scientific-technical enterprise, so that these groups do not look upon scientists and engineers as "they," but rather as a part of "us."

There are three dimensions of the human resource issue:

a. Is the opportunity to participate in finding solutions to the nation's most pressing problems unfairly denied to a substantial fraction of the population?
b. Can a sufficient number of American scientists be trained without the full participation of women and minorities?
c. Will the expansion of research resources tied to visible societal goals attract the participation of minorities who otherwise would not pursue a scientific career?

At the November 2000 Conference, Vivian Pinn pointed out that "the NSF report this year on women in science, mandated in law by Representative Connie Morella (R-MD), showed that in 1997 women constituted 23 percent of the S&E labor force. There was no progress from 1993 to 1997, and in computer science progress has been retrograde." Paula Rayman observed that in a 1972 conference, at the New York Academy of Science, on women in science, participants hoped that by the year 2000, women would achieve parity with men. Not even half that goal has been reached in most disciplines. In new fields, like computer science, women made big inroads, but plateaued, in the 1980s, at 34 percent, and ever since female participation has been on the decline. In some fields, like medicine and life sciences, women are fairly represented numerically in graduate and professional schools, but remain underrepresented in senior positions, and face continuing obstacles to professional advancement. As Jaleh Daie noted, "the task is greater than any one sector's ability to rectify the deficiencies. We must leverage resources by creating strategic and lasting partnerships between the private, public and non-governmental organizations (NGOs) sectors. These partnerships are essential to achieving long-term, systemic structural reform. A new forum based on the four Cs; Communication, Cooperation, Coordination and Consolidation is needed to facilitate and create strategic alliances…we know we have achieved equity when participation of women is unremarkable, natural and taken for granted."

Our conclusion is that to mobilize the indigenous human resources required to address the nation's critical problem, to ensure that the scientific community and the citizens whom they serve are in tune with each other, and to bring to Jeffersonian science the values and perspectives of the broad spectrum of Americans, the government's research strategy must have an effective component of a more diverse and more attractive educational system in science and engineering.

Moving Forward: Jeffersonian Research Strategies as a Central Feature of U.S. Science Policy

Lessons Learned

Broad acceptance of the Jeffersonian science concept: The applicability of a Jeffersonian approach is accepted, at least in principle, by a broad spectrum of policy makers, scientists, and politicians. In the two-year history of this project we have experienced a ground swell of support for the idea and very little challenge to it. The question is how to move such an approach to the center of science policy formulation.

Importance of properly defined national goals: Previous and ongoing initiatives have demonstrated broad support for categories of goals, such as quality of life and health, sustainable economy, environmental and natural resources, and security. The process of determining suitable goals and the science to achieve them must take the form of an extended national discussion involving all stakeholders.

Importance of constituents and the public to the formulation of science policy: stable funding for curiosity-driven research that supports broad societal goals must rest on a consensus of strong, supportive, public constituencies.

Structural change is required in governmental and policy processes: Sustained public expenditure and multi-year budgeting, the need for interagency coordination and shared terminology, high-level non-governmental evaluation of long-range research projects, and expanded resources for OSTP should all be part of adapting U.S. science policy to the realities of the 21^{st} Century. There seemed to be a general accord with Bill Bonvillian's observation that "there is a big need to rethink the structure of the science portfolio and the concept—whatever we call it—needs serious debate." There is also a need for mission agencies to renew their commitment to their intellectual roots.

Changes within the science community: The scientific community needs to undergo a number of changes in order to positively affect and enhance the nature of U.S. science policy and its ability to meet national challenges:

- Need for improved communication between the scientific community and the public and policy-makers,

- Differentiation between macrolevel policy agenda setting, and microlevel scientific research—individual grant applicants would *not* need to become the principal defenders of the social outcomes side of their research.

- Expanding the base of scientific human resources is crucial to the future of U.S. science policy. Linking social and national issues to science can have a strong impact on attracting women and minorities to what was previously considered predominantly a white male domain.

There is no one-size-fits-all solution: Each national issue requires a unique process for creating the research strategy. The case discussions on education, energy, and global climate change demonstrated the tremendous variance in the adaptation of a Jeffersonian strategy to a given issue.

Integrating the social sciences: There is a need for stronger integration of the social sciences into the process of formulating research strategies linked to societal outcomes.

Moving Forward with Jeffersonian Science—Key Issues

Individual and professional society initiative is crucial: It is vital to stress that we are not calling for a top down initiative, but rather the active participation of everyone reading this Report. The sources of change identified over the past several years are multiple and varied, and not limited to the higher levels of policymaking and government. Initiatives to create the research strategies we envision might come from groups of scientists, from science agencies in government, or from groups of concerned citizens. All will need to participate in defining the goals and setting the strategies.

Continued growth of public investments in Newtonian science, pursued without regard for applications is essential at the same time that Jeffersonian research strategies are put in place. Neither is a substitute for the other.

A national conversation on the future of science policy must be composed of a series of ongoing stakeholder conversations. These conversations must be designed in a way that encourages not only evaluation within the various groups and communities involved in science policy, but must also cut across traditional boundaries. Scientists must listen to and inform government officials, public constituents must be strongly involved in the formulation of national goals and policies, agencies must represent the importance of the science to politicians.

Measuring the results of Jeffersonian science is a crucial component to success. David Guston pointed out that the Jeffersonian science frame begs some critical questions: How do we evaluate—by what mechanisms and standards—the results of Jeffersonian science, and what do we do with the evaluations? Jeffersonian science invites us to examine the how's of connecting research outputs to social outcomes. We have limited tools for limited assessments, e.g., licensing income for economic benefit. But can we develop others?

Comprehensive analysis of existing models, such as NIH and NSF, will help guide the expansion of Jeffersonian strategies to other national issues and goals. Both the successes and the shortcomings of current efforts can and must inform future policy.

The cases identified in the conference—education, energy and climate change—should be the subject of a broader exploration in order to devise appropriate Jeffersonian strategies. Experts from the relevant fields of science and policy, and the public should be brought together for an ongoing discussion as to how to connect the best science to the most problematic areas of these important national issues. As mentioned above, no single formula will work for all issues—strategies must be crafted on a case-by-case basis.

Coda

Few will disagree that the achievements of science and technology are going to be preeminent among the determinants of what makes a nation great in the 21^{st} century, as economic potential, military might, and the social fabric of society ever more closely depend on scientific and technological progress. To a large degree, our civilization will only continue to flourish to the extent that science and technology continue to perform in the service of excellence and of the common weal.

One of the obstacles to embracing this truth, and acting upon it, is a certain shortsightedness, an unwillingness, within society at large, and the political system in particular, to wait for delayed gratification. Such an attitude hurts both the achievement of progress toward social goals but also the support for basic scientific research whose potential social benefits, although in many instances very real, often become evident only at a longer view. Our Initiative is intended to ameliorate this problem by strengthening the coupling of basic research and social needs.

To summarize our chief argument: We have proposed an integrated tripartite strategy of federal science policy that adds a third mode to the federal research portfolio, which customarily has been understood in terms of a dichotomy of basic and applied research. To be sure, both applied research that transforms theoretical knowledge into useful products and services, and curiosity-driven basic research that, as the record of the past decades amply demonstrates, has led to unpredictable spin-offs of enormous societal value, will remain vital to a healthy national science enterprise. But the addition of a third mode—basic science that is targeted in an area of important societal objectives, or Jeffersonian science—is likely to bring about specific major advantages over the current system. First, it will enable science to do even more, and more quickly, for society than science is currently being asked to do, and it will thus speed societal progress. Second, it will make the link between basic research and public objectives more obvious, so that the public will have a greater appreciation of the benefits of science, and will be inclined to provide increased and stable support not only for Jeffersonian science, but for the whole scientific enterprise. And finally yet importantly, it will enhance science's claim to moral authority, which any enterprise, including science, deserves insofar as it is understood to serve the public interest.

These are not radical or untried notions, especially not in American history. As long ago as 1743, Benjamin Franklin sparked the founding of a scientific society "for Promoting Useful Knowledge." And in 1780, John Adams gathered a group of his colleagues to create an organization "to cultivate every art and science which may tend to advance the interest, honor, dignity, and happiness of a free, independent, and virtuous people."

Having entered upon a new century, with its own dangers and opportunities, we remain committed to these same aims, as worthy now as they were then.

Endnotes

1. Basic scientific research is a concept popularized by Vannevar Bush in *Science—The Endless Frontier*. Bush believed the creativity of basic science would be lost if it is constrained by premature thought of practical use, a concern that motivated the sometimes challenged distinction between basic and applied research. Many authors prefer "fundamental research" (to characterize its outcomes as contributions to understanding of nature), or "creative research" (to describe the conditions under which it is performed) over "basic research" (emphasizing the curiosity-driven motivation). All three (strongly related) definitions, based on the motivations of the investigator, outcomes, or conditions of research, say nothing about the motivation of the sponsor of the work.
2. *Ivory Bridges: Connections Between Science and Society*, Cambridge, MA: MIT Press (forthcoming).
3. Some may ask whether the concept of Jeffersonian research is essentially the same as Donald Stokes "use-inspired basic research" or research in Pasteur's Quadrant of Stokes's two dimensional diagram distinguishing "pure basic research," pure applied research" and use-inspired basic research [Pasteur]. Stokes sees Pasteur's quadrant primarily in terms of mixed motives by the investigator—both intrinsic curiosity and extrinsic social value. He recognizes and discusses, of course, public motives in sponsoring such research for its social value. But he does not recognize the need for a conscious strategic plan to pursue a long range, "basic" agenda justified by pursuit of a social goal. That is, of course, the distinction between Jefferson—a public official who created a charter and provided the resources but did not do the research—from Pasteur, who created his own mixed-motives agenda from a variety of resources. Thus the concept of Jeffersonian science takes Stokes's ideas one step further, providing a reasonable justification for using Jefferson as the metaphor rather than Pasteur.
4. Gerald Holton and Gerhard Sonnert, *Issues in Science and Technology*, Fall 1999. They use "Jeffersonian Science" and "Jeffersonian Research" synonymously.
5. The best of the corporate research laboratories such as Bell Labs and the IBM Watson Laboratory have long practiced a management style in which research managers choose fields and recruit research staff with a keen eye to the likely commercial value of the research, relying heavily on self-motivation of the researchers to be both imaginative and productive. Those researchers are, of course, well aware of the needs of the company and do not require much urging to look for opportunities to make a corporate contribution.

6. Baconian research, by contrast, is not only motivated by specific, mission-oriented goals but entails the application (and perhaps extension) of existing knowledge to the achievement of such goals, usually with constrained time tables and resources.
7. From a science policy point of view the place of both Jeffersonian and Newtonian s cience in national policy follows directly from the distinction, popularized by Harvey Brooks, between "science for policy" and "policy for science." Jeffersonian science follows logically from the government's need to inform policy on issues facing the nation with the best understanding from science. Newtonian science follows logically from the importance of "policy for science"—the obligation of government to ensure the most vigorous, imaginative, and internationally competitive capabilities in science and technology.
8. "The War on Cancer", *U.S. News and World Report* (www.usnews.com/usnews/issue/cancer.htm).
9. The Commission seriously debated the idea that some part of the NSF activity should merit priority from national goals to which the research might contribute, but the report language was quite muted. National Science Board Commission on the Future of the National Science Foundation: *A Foundation for the 21st Century: A Progressive Framework for the National Science Foundation* (Washington, DC: National Science Board, November 20, 1992).
10. *How People Learn: Brain, Mind, Experience, and School*, Bransford, John D., Ann L. Brown and Rodney R. Cocking, eds., (National Academy Press, Washington, DC) 1999.
11. *How People Learn: Brain, Mind, Experience, and School*, p. xxi (executive summary).
12. The growth of interest in distance learning (applied today to post-K-12 education) together with the growth of e-commerce might accelerate this possibility, especially since e-commerce allows geographically dispersed fragmented markets to be integrated. E-commerce and similar e-education shift responsibility for funding education from public venues to individual ones. The issue of what will be lost in the process should receive more attention.
13. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, U.S. Global Change Research Program, Published 2000/2001 (www.usgcrp.gov/usgcrp/Library/nationalassessment/default.htm)
14. U.S. Global Change Research (GCR); NRC, NSF (Envir. Sci and Eng. for 21st Century), IPCC reports.
15. See David Guston, *Between Politics and Science* (Cambridge University Press, 2000)
16. One observer noted "No one dies of 'general medicine'."
17. Thus the *New England Journal of Medicine* is more effective at conveying the value of biomedical science to the public than are any of the professional journals in biomedical sciences.

18. *National Patterns of R&D Resources: 2000-Data Update* (current to March 2001), National Science Foundation, (www.nsf.gov/sbe/srs/nsf01309/start.htm).
19. Allan Bromley stated that FS&T cut the ground out from under the argument for transferring defense R&D to civil R&D.
20. See Stokes 1997:64-70; Branscomb 1999.
21. The idea of "basic technology research" is explored in L.M. Branscomb, "From Science Policy to Research Policy" in L.M. Branscomb and J. Keller, eds, *Investing in Innovation* (Cambridge MA: MIT Press 1998).
22. Some people have suggested that OSTP should receive an operating budget so it could fund selected, long range research programs directly. Bromley specifically advised against this idea, for which there was no spoken support in the meeting.
23. NSF's Criterion 2 states: What are the broader impacts of the proposed activity? How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society? [NSF Important Notice No. 125, Sept. 20, 1999 (www.nsf.gov/pubs/1999/iin125/iin125.txt].
24. During the Vietnam War, scientists supported by the Department of Defense were required by the Mansfield Amendment to document how their research might improve military capability. This question should have been answered by the military agency project managers who had access to the needed information. If application values are to form part of the peer evaluation of project merit, the peer panels would have to include experts in the field of application, as well as experts in the relevant disciplines.
25. The Y2000 census has revealed that whites are now a minority of 47 percent of the population of California, home of a disproportionate fraction of the nation's scientific and technological capabilities.
26. Stephan-Götz Richter, "The immigration safety valve keeping a lid on inflation," *Foreign Affairs*, Vol. 79, No. 2.

37 The Impact of Terrorism on Academic R&D

Representative Sherwood L. Boehlert

I am sure that all of you, like me, are still reeling—emotionally and intellectually—from the attacks on the World Trade Center and the Pentagon. In every sense, from the personal to the national, it is hard to know exactly how to respond. In some ways, the passage of time has made what happened seem only more unreal and bewildering. But I think it is safe to say, that in the coming months, as in previous times of crisis, our nation will turn to its colleges and universities for help. Colleges and universities are inherently implicated in our response to September 11. We look to our universities for leadership, for ideas, for information, for education and training, and, if worst comes to worst, for soldiers.

While we say that the world changed on September 11, it is really our knowledge of the world, our sense of the world, and not the world itself that changed on that fateful day. After all, terrorists were at work before the 11th, the Taliban was in power before the 11th, and our security vulnerabilities existed before the 11th. It is our awareness of these and so many other aspects of life that is so different now. Only the ways we put that new awareness and knowledge to use will change the actual world in the aftermath of the attacks.

Academia, as a leading generator, analyzer, repository, and purveyor of human knowledge and insight, will necessarily have an impact on whether and how our world actually changes. I hope and expect that academia in general and the State University of New York (SUNY) system in particular are up to that task. It may require some new under-

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takings, but mostly it will simply require more intensive and better-focused attention on existing efforts, as well as greater engagement with the rest of American society. I do not believe that the attacks on September 11 signal a need for any fundamental change in the structure or nature of our academic institutions. I am thinking here, particularly, of the openness of our colleges and universities—openness to both ideas and people.

I have already seen articles in *The New York Times* and *The Chronicle of Higher Education* raising the specter of new restrictions on student visas, although I have not heard much talk of this yet in Congress. Obviously, the United States has to screen all visa applicants more thoroughly, needs to keep better track of those who enter our country, and, in particular, needs to crack down on those with expired visas. But we must not imperil the openness of our universities, which are magnets for students around the world, many of whom choose to settle in the United States and contribute to the advancement of our society. Foreign students who remain here are absolutely critical elements of our science and technology work force, and those who return home often increase the goodwill toward the United States in their home countries.

Some people may view limiting visas as "erring on the side of caution," but it is just as easy to argue that "caution" demands openness, given how much we rely on students who come here from overseas. Indeed, I believe we need to look critically at every proposal that curtails the general openness and freedom of American society in the wake of September 11. As a member of the House Intelligence Committee, I know that changes are needed, but these changes need to be targeted and limited.

Fundamental changes in the nature of academia are probably unwarranted, but what about changes in the research and development agenda? Do we need to redirect government or academic research and development (R&D) in the wake of the attacks? Along with the scientific community, the House Science Committee, which I chair, has just begun to analyze that question. I know that the National Academy of Sciences and numerous other entities in Washington and around the country are also looking at how the scientific community should respond to the attacks. But we must be careful, especially now, about rushing to conclusions.

My basic view is that, while there are a few areas that need additional focus, the general thrust of R&D need not change. I do see, however, some areas in which research has probably been inadequate. First among these appears to be computer security. While the terrorists involved in the September 11 events did not engage in cyber attacks (indeed they made full use of the Internet in carrying out the everyday activities, like purchasing airline tickets, on which their plot depended), our general vulnerability to terrorism should make us look again at our ability to protect the computer systems on which we all increasingly rely.

The experts tell us that we have a long way to go to make our systems secure. One reason for that is that research on computer security, particularly on security for civilian systems, is inadequately funded in academia, government, and industry. The computer science resources that attract the best computer scientists and engineers are simply elsewhere. That situation has been exacerbated by battles over who should fund what kinds of research. On the one hand are the security agencies (particularly the secretive National Security Agency) and on the other hand are the civilian R&D agencies. The Science Committee will soon hold a hearing to explore these issues more fully. Our conclusions will be reflected in the Information Technology bill we were already drafting on September 11, which will authorize and improve coordination of computer science programs across the federal R&D agencies.

The federal government must also put additional resources into improving the technical capabilities of our law enforcement agencies. We need research that will enable us to gather better intelligence to foil terrorist plots and other crimes before they are implemented. I am quite familiar with this work because some of it is going on at the National Institute of Justice (NIJ) lab, which is working with the Air Force's Rome Lab at the former Griffiss Air Force Base in my district. The NIJ center was doing a great deal of work with the Secret Service and the Federal Bureau of Investigation offices that were located in the World Trade Center complex. They head a federal, state, and local government partnership called the New York Electronic Crimes Task Force. Their building—Building Seven—was among those that collapsed, but thankfully, everyone in the Task Force got out safely. Within days of the tragedy, our NIJ center in Rome as well as other New York assets helped to get the Task Force up and running again. (When I was in New York City to tour "Ground Zero," we were told that access to the Building Seven area is being strictly limited and that all the materials from Building Seven—metal, paper, concrete—are being kept separate from the rest of the Trade Center debris at the Fresh Kill Landfill for security reasons.)

There are probably some narrower areas of research that also need more attention. For example, the Science Committee is working on a bill to authorize the Environmental Protection Agency (EPA) to fund research to assess and improve the security of our drinking water systems. This idea came to us from the water utilities; the sewage authorities are interested in similar research on their facilities. Unlike the other areas I discussed, none of this is likely to be particularly fundamental or basic research, but it is still vitally important, and universities will no doubt have a role to play in it.

Other research projects may emerge as we scrutinize what happened in New York and Washington, DC. We plan to hold a hearing later in October to examine what research is needed to better protect our physical infrastructure—buildings, power plants, the electric grid, etc. My staff and I are working with Governor Tom Ridge and his Homeland Security Team on this.

In addition, the focus of some of our nation's research may shift. Existing research on identification techniques must get a higher priority (especially biometrics—the use of iris patterns, heartbeat patterns, or other aspects of the human body to ensure that people are not using false identities). Research in the social sciences and the humanities, including research on the causes of terrorism and the reaction to it, will certainly be more relevant now than ever before. Research that would help us prevent or respond to chemical, biological, or nuclear attacks by terrorists will also have renewed significance. As has been noted often, the September 11 attacks were not exactly high-tech. The terrorists turned the instruments of everyday American life against us. We need careful analysis to piece together how the terrorists accomplished that, and, to the extent possible, to prevent its recurrence. But that is, by and large, not the stuff of a wholly new federal or academic R&D agenda.

The rest of my remarks will address some things I would like SUNY and the nation to focus on that have not been directly affected by recent events, namely the bulk of our R&D and education programs.

The good news is that federal R&D spending was doing fairly well in the congressional appropriations process before September 11, and that is unlikely to change as the process concludes. (As FY 2002 begins, we have yet to complete action on a single spending bill. This is understandable in view of the events, since September is usually the month for working out the details in the appropriations process.) For example, the FY 2001 spending level for the National Science Foundation (NSF) was about $4.4 billion. The President—misguidedly, I believe, but without prejudice—recommended essentially level funding for FY 2002. But the House intervened and provided more than $4.8 billion, and the Senate almost $4.7 billion. Now that the White House and congressional leaders have tentatively agreed to raise overall federal spending for FY 2002, I expect NSF to end up with a sizable spending increase for the new fiscal year. More resources will be devoted to R&D, as Director of the Office of Management and Budget Mitch Daniels has agreed.

Federal increases should only bolster New York's efforts to build up more centers of excellence in New York State. Governor George Pataki, State Senator Joseph Bruno, and SUNY chancellor Robert King are looking for ways to bring together our state's public and private universities and colleges with industry to create such research centers. The Governor's high-tech initiative for $1 billion deserves credit and praise. Senator Bruno's Gen*NY*sis (Generating Employment through New York Science) Program does too. Both focus on one of New York State's greatest assets—the SUNY system. The Pataki/Bruno/King team is moving in the right direction at an accelerated pace.

Our economic competitors are doing the same thing, with gusto. As our national economy falters, New York needs such centers now more than ever in order to be competitive. In 1998, New York State ranked eighth among states in receipt of federal research and development funds—a respectable ranking, but hardly up to our potential, given our academic and industrial base. In terms of dollars, New York received less than one-quarter of what top-ranked California received. That has got to change. And our rivals are hardly resting on their laurels. The State of California, for example, is planning to invest $400 million over four years in new multi-disciplinary Institutes for Science and Innovation located on University of California campuses.

The entire New York State congressional delegation is committed to ensuring that New York gets its fair share of federal funds. We have already had several meetings with chancellor King in Washington. New York's presence in the nation's Capitol has a much higher profile since September 11. But when it comes to securing federal funds for the necessary programs in any state, members of the scientific community are the ones who truly hold the keys to our success. Our efforts before federal agencies and our congressional colleagues can be successful only if we are advocating for credible, high-quality plans that have been well thought out in advance. Among other things, these plans must ensure that our work to expand New York's R&D enterprise only strengthens the educational mission of our colleges and universities. None of the R&D we conduct on security or anything else will matter, in the long run, unless it helps train students in new fields. None of our R&D goals will be met, in the long run, unless we do a better job of preparing teachers and producing more capable students in science and math.

Finally, I want to discuss education in general. Recent events have done nothing to deter the President and Congress from carrying out their commitment to improve American education, particularly pre-college education in all fields, not just science and math. President Bush has made education one of his signature issues. Negotiations continue to increase funding levels for education programs and to enact a major rewrite of the Elementary and Secondary Education Act. Congress should be able to pass that legislation by the end of October, which should gradually result in better prepared students arriving on our campuses.

Progress is also being made on the National Mathematics and Science Partnerships Act (H.R. 1858), a bill targeted specifically at improving pre-college science and math education. This bill would create new NSF programs to encourage institutions of higher education as well as businesses to devote more of their energy and resources to improving pre-college education in these fields. The bill would also create new federal scholarships to encourage top science, math, and engineering majors to become science and math teachers. I introduced this bill, which builds on proposals from President Bush and Members of Congress on both sides of the aisle. It passed the House without opposition and is garnering bipartisan support in the Senate, where it was introduced by Senator Jay Rockefeller (D-WV). Money for two programs in the bill—partnerships between universities, colleges, businesses, and school districts and the scholarship program I mentioned above—are already included in the House spending bill for NSF. We are on our way to seeing these programs implemented. I hope to see SUNY campuses participate actively in these programs once they are in place. We have consulted with the chancellor and his team every step of the way in the development of this legislative initiative. All of our institutions of higher education must redouble their efforts to improve science and math education at the K-12 level. The full range of SUNY institutions—community colleges, four-year colleges, and university centers—all have a role, regardless of whether they have education departments.

I should note that Senator Joseph Lieberman (D-CT) and I also plan to introduce a bill to put more federal resources into improving science, math, and engineering education at the undergraduate level. In fact, we had a press conference on the bill scheduled for September 11.

The events of September 11 have forced us to alter our agenda in ways large and small. But fundamentally, our nation's R&D and education needs remain basically what they were before the attacks. For now, at least, the resources available to meet those needs remain about the same as well.

We need to draw on, and shore up, the strengths of our major institutions, such as SUNY, not just to prevent future attacks, but to ensure that our nation remains a beacon of freedom, openness, opportunity, innovation, and prosperity. These traits may make our nation a more appealing target for terrorists, but they are also what makes our nation the great one it is and worth defending.