Opening Remarks

Provost Jonathan Cole

COLE: In the 50th anniversary year of the publication of *Science: the Endless Frontier* (1945), the challenge that confronts us is to learn from the past and design for the future: not simply to celebrate what was begun by Vannevar Bush and his colleagues, who formulated a plan for the growth of American science in the aftermath of World War II; not simply to opine about what may seem to some today like the halcyon days of the past when we witnessed enormous rates of growth and scientific resources that produced exponential rates of growth in scientific knowledge. In short, we should not try to socially construct the golden past or a lost Eden, one that surely never existed.

Rather, we should engage collaboratively in the analysis of the intentions and purposes behind the creation of the Bush model that led to the close partnership between science and American research universities. We should think critically and analytically about the historical achievements of American science and technology, as it has operated within the framework of the Bush manifesto over the past half century. We should analyze the strains in the alliance or partnership – the sources and types of breakdowns in the system that we have created. And finally, we should develop new ideas for a reconstructed model of science in the national welfare that will serve the nation as well over the next 50 years as the Bush structural model has over the past half century.

In reviewing the history and context in which *Science: the Endless Frontier* was produced, we are made keenly aware of the multiple purposes and motivations behind the Bush report to President Truman after President Roosevelt's death. A principal objective of Bush and his colleagues was the continued importance of maintaining military superiority for the United States. This, they reasoned, would require heavy investments by the government in defense-related research at universities and national laboratories.

Second, in reflecting on the past, we try to get the history right and to speculate on motivation and intention, as well as on the unanticipated consequences of the creation of the structure derived from the differing organizational perspectives championed by Vannevar Bush and Senator Harley Kilgore, Democratic Senator from West Virginia.

We can now perceive how much the model that led to the National Science Foundation and to the thorough institutionalization of the National Institutes of Health grew out of a national military crisis. We can see how the design for investments in science and technology was pieced together rather rapidly but represented perhaps the most systematic, nationally organized effort ever to structure the support for scientific and technological growth – one that understood how investments in young people and their education at the finest American universities could create American superiority and preeminence in the production of knowledge in these areas. This vision was remarkably prescient. And its implementation has brought truly extraordinary benefits to American society.

Fifty years later, we venture into more difficult terrain. We must analyze the consequences of the partnership between government and university-based research and discern how the areas of knowledge and practical activity outlined by Bush in his report affect human health, economic change, national security, and investments in human and intellectual capital and public welfare. We have expanded that angle of vision to include the consequences on studies of the environment and the social problems beyond those that are directly health-related.

We must also inquire into the many achievements as well as some of the failures of the structure of scientific and technological innovation that we have created over the past half century. We must describe how this system of national innovation led directly to an organized arrangement for scientific growth perhaps unequaled over the past several hundred years. But we must also analyze the unanticipated positive and negative consequences of this system of innovation – the displaced scientific and organizational goals, the missed opportunities as well as the opportunities seized, the organizational and structural problems as well as successes of the Bush paradigm.

As we reflect on the system of support for science and technology that has dominated our society over these past decades, let us not fall prey to hyperbole in extolling virtues and overstating shortcomings. The system has been around a long time, demonstrating extraordinary vitality. We continue to produce extraordinary science and technology. We have not lost our scientific capabilities or imagination. We continue to produce exceptional talent among our younger population. We continue to attract some of the brightest young people in the world, who want nothing more than to study with American scientists and engineers.

Indeed, science and technology, which are fundamentally dependent upon federal resources, have expanded and grown at rate that was never dreamed about by the founders of the system. American science and technology has been the dominant social system of science during the post-war period. Perhaps the central message of the history of the Bush era of scientific development is one that emphasizes rapid growth and unparalleled successes in the advance of knowledge. Much in the system remains strong, but it is under strain, and not only from Washington lawmakers. Even if the system is not totally broken, and I do not believe it is, it is an old system and is clearly suffering from serious fatigue.

The partnership between the federal system of support and the university as the principal site for innovation is under severe strain today. While the system is not coming totally unglued, even if the current scene in Washington might lead us to believe otherwise, let us acknowledge that the national system of innovation needs some serious rethinking, reconceptualization, and perhaps some restructuring.

This should not surprise us. The positive heuristic of any system is apt to become tired if not exhausted over time, if for no other reason than that the context changes. The society that produced it has evolved in important ways that make the older model problematic. And the social context in which we are producing investments in science today is markedly different from that considered by Bush and his colleagues. More importantly, the external threat of Communism no longer dominates the perspective of policy makers in Washington. The Cold War is over.

One significant rationale for the Bush plan has limited saliency today. While the results of fundamental research in the biological and health-related sciences are still only in the early stages of reaching their full potential to understand and prevent disease, the system of health care is in a transitional, if not chaotic state. And the relationship between current health care costs and needs is clouding the issue surrounding investments in basic biological and health-related research.

There would also seem to be a crisis in industrial commitment to basic research, with many of the industrial laboratories downsizing to the point that questions of their future vitality may be legitimately raised. There remains little commitment to research in the social and behavioral sciences with little apparent understanding of the critical importance of focusing on the interrelationships between social structures, social systems, and primary foci of scientific attention. Whether the problem is preventing transmission of AIDS, preventing substance abuse, an epidemic of violence in the streets and in families, suicides among America's youth, or investments in the human capital through education, these social aspects of public health have yet to be woven into the fabric of national innovation and remain constant objects of skepticism.

And finally, the number of those among critical policy decision-makers who fully understand the national payoffs to investments in science and technology seems to be dwindling, a fact for which we in the scientific and academic communities are partially responsible. In one sense, of course, all of this is familiar. Most great organized efforts at scientific advance have had goals similar to those articulated by Vannevar Bush and his colleagues. As we know, for instance, in the 17th Century, the Royal Society was formed and as Robert K. Merton put it in *Science, Technology, and Society in Seventeenth Century England* (1970):

> 'Science was to be fostered and nurtured as leading to the improvement of man's lot on earth by facilitating technologic invention. The Royal Society…does not intend to stop at some particular benefit but goes to the root of all novel investigations. Further, those experiments which do not bring with them immediate gain are not to be condemned, for as the noble Bacon had declared, experiments of Light ultimately conduce to a whole troop of inventions useful to the life and state of man.'

The analytic question is how the systems of innovation have been organized. What caused them to be organized as they have been? And what values, norms, and structural factors have been related to the successes and failures of these social systems of innovation?

Bush envisioned the creation of communities of scientists and engineers at universities as a means towards furthering the advance of individuals. The individual is adumbrated also in the operation of the Royal Society and its relationship to science at Cambridge. In reflecting on the Merton thesis in *Puritanism and the Rise of Modern Science* (1990), I.B. Cohen noted,

> 'Newton's career also illustrates an important observation by Merton on the significance of the formation of a scientific community; almost certainly Newton would not have written his *Principia* had there not been a discussion by the

> London virtuosi of the Royal Society of the possible force responsible for the observed Keplerian motion in the planets. It was as a result of this discussion (by Hooke, Wren, and Halley) that Halley went to Cambridge to see Newton and to explore this topic with him. The subsequent encouragement of Newton by Halley and the approbation of the Royal Society were significant factors in pushing Newton to complete his researches and write them up for publication under the Royal Society's imprint. It is doubtful that without the Royal Society there would ever have been a *Principia*.'

It is our principle mission to begin to understand better the changed landscape and environment for science and technology, and how it is affecting the operation of a system created more than 50 years ago. What our analysis tells us ought to be recast in the current partnership between science and universities. We must focus on the achievements of the Bush paradigm as well as on the points of strain in the current system.

I'd like to suggest a number of themes and questions that, from the perspective of an inveterate sociologist of science, ought to be addressed.

First, in each of the primary areas of research considered, what have been the most significant achievements resulting from the Bush system of innovation? And what structural features of the system can be credited for facilitating these successes? In fact, how have the organizational principles and structure of resource allocation used to identify scientific talent and problems meriting exploration at the National Science Foundation (NSF) and the National Institutes of Health (NIH) determined the outcomes of the research? In short, why has the Bush model been so successful for the better part of a half century?

Second, in what ways has the Bush model's explicit prescription to link basic research at universities with the training of the next generation of scientists and engineers been essential for the productivity of science and technology during this period?

Third, how essential has the peer review system been for the successful development of the basic sciences and engineering? What are the problems with the peer review system today? And in what ways, if any, has it become dysfunctional for the continued and sustained growth of scientific knowledge?

Fourth, the normative ethos of science, which was reinforced within the Bush framework of innovation, emphasizes an open system of knowledge, production and communication. Can a system flourish that limits such an open society? Are we experiencing greater pressure to limit the free distribution of the fruits of science and technological innovation? And if so, what are the consequences for the production of knowledge and its uses?

Fifth, while there is some significant political pressure for scientific isolationism, will a modified national system of innovation have to be structured in such a way as to share responsibility even more with our international communities, both of scholars and nation states?

Sixth, what role should industrial research and support for science and technology play in the tripartite and remapped system of innovation? How should the current roles be altered?

Seventh, how will the shape of scientific communities change in the restructured system of innovation? Will the traditional and visible colleges undergo significant substantive reconstruction with the further development of communications technologies? How will this affect scientific publication and the reception of published work? How will the information revolution affect the role of the traditional scientific journal and methods of peer evaluation at work? And how will all of this influence the existing system of organized skepticism, that critical piece of the evaluation system of science?

Finally, are there real threats to the scientific enterprise coming from those who take a strong relativist or social constructivist position about the development of knowledge, and who believe that the scientific method and its results are little more than a matter of social consensus and power relationships? Or is the anti-science movement one that represents a passing intellectual fashion?

Consider a few more problems with the current system of innovation. The system has become extremely large, competitive, and bureaucratic. Scientists and engineers appear to be experiencing significant displacement of goals. Scientists spend an inordinate amount of their time obtaining resources to conduct science, impeding their efforts to actually remain active researchers. There are now scientific rainmakers whose principle occupation is finding resources for large numbers of workers in their local scientific vineyards. There are continual problems raised about the nature of the process of funding research. Is it fair? Does it approximate a meritocracy? Does the system of resource allocation match the types of problems being attacked? Does it place too much of a premium on the quality of proposals rather than the track record of the scientists and engineers? Are priorities too often set for political rather than substantive scientific reasons? Is this resource allocation system undermining the interests of young, potentially talented scientists and engineers?

Has the system supported too many people, programs and universities without sufficient concentration of resources? What is the optimal level of competition in the national system of innovation? And how would we know when we have reached it?

To what extent is the strain in the Bush model a function of the relationship between the number of scientists and the availability of resources to carry out science? Or does it lie in the structure of the system itself? Is the system producing too many scientists and engineers given the labor market for such highly-trained members of society? How do we begin to calibrate the production of scientists with the larger labor markets in need of their talents?

The current system seems to inhibit the development of criteria of scientific choice among competing claimants to scientific resources. Almost 40 years ago, Alvin Weinberg spoke of the need to articulate such criteria. I'm not aware of any effort that has succeeded in establishing a basis for determining scientific priorities. Should that be a goal of a national system of innovation? These and other questions need to be developed.