

Design Area Five:
Basic Research and the American Research Universities

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(MISSING TAPE)

COLE: –through some of the aspects of the Vannevar Bush framework and as we try to think about the issues, the questions, the problematics that are part of any effort that might be made to redesign that framework in light of changing times and changing conditions, as we look forward to the next decades in American science policy. I, for one, found the presentations and the discussions extremely interesting and fruitful in generating ideas for additional work that will follow this conference.

So, we turn this morning to the session that is very dear and close to my heart and that has to do with basic research and the American universities. I think it is fair to say that Vannevar Bush, in *Science: The Endless Frontier*, had this very much in mind as he talked about the answers to the four questions that were put in the letter from President Roosevelt and then later delivered to President Truman. When he talked not only about national security but the public welfare, he talked indeed, as it was mentioned yesterday about full employment, how basic scientific research is scientific capital.

In answering the question "How do we increase the scientific capital?" he said, "First we must have plenty of men and women trained in science. For upon them depends both the creation of new knowledge and its application to practical purposes. And second, we must strengthen the centers of basic research which are principally the colleges, universities and research institutes."

Indeed, over the past 50 years, that linkage has been an extraordinarily important one, both for the research universities, of course, as well as for the production of new knowledge. He goes on to make the very important additional point that there ought to be a coupling of the education of graduate students and professionals with graduate education at these universities, supported through fellowships and scholarship programs. Where education and research are really joined has been one of the hallmarks of the period that we review at these conferences.

So, I look forward enormously to the comments that we have from our presenters and our panelists. It's a great pleasure to introduce the first policy design presenter, and that is James J. Duderstadt, who is now president emeritus and university professor of science and engineering at the University of Michigan, one of the nation's true leaders in higher education over the past decade. Jim Duderstadt received his bachelor's degree in electrical engineering from Yale in 1964 and his doctorate in engineering science and physics from Cal Tech in 1967. After serving a year as the Atomic Energy Commission Fellow at Cal Tech, he joined the faculty of the

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University of Michigan in 1968, as professor of nuclear engineering. He became dean of engineering in 1981 and then provost and vice president for academic affairs in 1986. He was named president of the University of Michigan in 1988 and served in this role until 1996. It's a great pleasure to have Jim Duderstadt with us today. Jim Duderstadt –

DUDERSTADT: Let me add my gratitude and express my surprise for this turnout on this remarkable fall day. I should point out that this is the first fall Saturday in ten years that I don't have to worry about something else happening involving 22 young men. I can join my colleagues, such as George Rupp, to focus on intellectual matters on Saturday.

Actually, I do have another worry. This afternoon, for the first time in history, another college football stadium, that of the University of Tennessee, will presumably set the new record, surpassing Michigan's record of 106,900 in attendance. Hey, not to worry. Not my problem. Not my watch.

Let's focus instead on the remarkable social contract that has existed between the universities and the federal government as laid out in Vannevar Bush's report, *Science: The Endless Frontier*. It does reflect a unique character of higher education in America, in the strong bond that exists between our institutions and the society that shaped them, supported them, and so forth.

The partnership between the federal government and the universities for the support of basic and applied research really did carry on that theme. It's had a remarkable impact. Shaped the universities, a remarkable institution, such as the one we're meeting at today. It's made America the world's leading source of fundamental scientific knowledge. Produced well-trained scientists and engineers. And addressed many of the most critical issues facing our nation in a broad range of areas from national defense to health care to agriculture to economic development.

Largely as a result of this policy, the American university today, the research university, is regarded as the strongest in the world, at a time when the investment returns in research have never been higher. Many of you remember two or three years ago when The New York Times, in an editorial, referred to our nation's research universities as the "jewel in the crown of our national economy," going on to assert that university research is the best investment taxpayers can ever make in America's future.

And yet, the 1990s are a time of great stress and concern for many of this nation's most distinguished campuses. There is a sense of a breakdown of mutual trust that all too often has led to an adversarial relationship between the federal government and our institutions. A certain level of skepticism, even hostility exhibited by the media and government, which has badly eroded public trust, as revealed by a deluge of attacks on the academy. Forces upon and within universities, pushing them to rebalance their missions, to shift away from research toward teaching and public service. Signs that the morale of our scholars, our researchers on campus, has deteriorated significantly over the last decade for many reasons – the time-consuming and difficult nature of obtaining funding, the disintegration of a scholarly community, concerns about the future.

Many things are going on here. To some degree, it represents a cyclic view of our society about the importance of scientific research. There may be a certain level of populism, of suspicion, of distrust of expertise, elitism, of excellence. But I would contend that something else has happened, a very fundamental change is underway, both in the nature of the relationship between our universities and the societies they serve, and in the character of those universities.

Let me make some brief remarks on both. First, the research partnership itself. A topic that, I suspect, you have considered in some detail yesterday and in many other forms is the shift that has occurred in national priorities over the last decade, to put it simply, from guns to butter. For almost half a century, the driving force behind many of the public investments in our national infrastructure has been the concern for national security in the era of the Cold War. In the wake of extraordinary events that have occurred in recent years, our nation is, instead, drifting to define new driving priorities. Far from a peace dividend providing new resources in the post-Cold War world, what we find is an ambiguity.

Although numerous societal concerns are now mentioned to succeed national security – national health care, crime, K-12 education, economic competitors – none of these has yet assumed an urgency sufficient to set new priorities for public investments. And therefore, much of the existing intellectual infrastructure developed to underpin national research is now at risk: the national laboratories, industrial R&D laboratories, and, of course, the research university itself.

Second, there's been a change in the character of the relationship between the university and the federal government. *Science: The Endless Frontier* stressed the principle that the government had to preserve freedom of inquiry. That is, to recognize that scientific progress results from the free play of free intellects working on subjects of their own choice in a manner dictated by their curiosity for the explanation of the unknown.

Since government in years past recognized it did not have the capacity to manage effectively research in the universities, the relationship was a true partnership. The government provided fairly unrestricted grants to support a part of the research on campus, with the hope that wonderful things would happen. And, of course, they did.

Unfortunately, in recent years, the basic principles of this extraordinarily productive research partnership have begun to unravel, so much so that I think today one might more properly characterize the relationship as evolving from a partnership to a procurement process. The government is increasingly shifting from being a partner, a patron of basic research, to becoming a procurer of research, just like other goods and services.

In a similar sense, the university itself is shifting to the status of a contractor, regarded no differently from other government contractors in the private sector. A grant is viewed as a contract, subject to all of the regulation, oversight, and accountability of other federal contracts. Speaking as a has-been university president, but a very recent has-been university president, this particular view has unleashed on the research university an army of government staff accountants and lawyers, all claiming that their mission is that of making certain the university meets every detail of its agreements with the government.

Third, there is a significant shift in public attitudes. What is at risk today is that a national consensus, decades in the making, that saw universities and faculty as fundamental investments in the scientific, technological, and scholarly preeminence of the nation is beginning to unravel.

This particular consensus, which married research and scholarship, which gave rise to the concept of the faculty as teacher/scholars, is now beginning to change. And it's pushing many of our institutions to regard their faculty as simply teachers. I think one of the interesting premises to arise, and it was pointed out in some of the early discussion papers associated with this particular session, is the challenge to the conventionalism that research and teaching should go together.

This is, in fact, much of the tradition behind many of the particular policies of universities and federal programs. I would quote in specific a policy statement of the National Science Board in the most recent issue of the *Science and Engineering Indicators* – that the integration of research and education is in the national interest and should be a national objective and, to advance this goal, federal science and engineering policy should strengthen efforts to promote the integration of research in education at all levels, supporting innovative experiments in this area.

And yet, in contrast, we're beginning to hear signs that perhaps this is not the right direction to go. My former boss, Harold Shapiro at Princeton, one time noted a growing sense that the competitive demands of specialized scholarship have created an irreparable rift between graduate and undergraduate educations. And it may have impaired the capacity of research universities both to remain centers of modern scholarship and to fulfill their broader educational functions. As President Shapiro put it, "the predicament today is that the faculty is indeed transmitting what they know and love, but with little awareness of what the student needs to learn."

Bob Atwell, in his final letter after stepping down from the American Council of Education two weeks ago, focused on graduate education at the root of much of our problems. We all, of course, view doctoral education as the crown jewel of American higher education, certainly the envy of the world. But Atwell argues that there's a mismatch today between doctoral education and the higher education marketplace, which is much more central to our difficulties.

He argues that too many faculty in our research universities are out of touch with the main stream of higher education, not to mention societal changes and fiscal realities, and so they go on trying to clone themselves in the persons of their graduate students to assist in their research. And yet, even those few graduates who are employed in higher education are unlikely to be employed in research universities.

Rather, they'll be employed in that far larger body of four-year comprehensive institutions, community colleges, in which education is the primary mission. And yet, because of their training, often frustrated, these new younger faculty pressure these institutions toward becoming research universities themselves.

In a sense, these kind of changes reflect the profound nature of the challenges and changes facing higher education itself. University presidents grapple every day with the current political

economic crisis, the imbalance between revenues and expenditures, that characterize governments at the federal, at the state, and at the local level.

While much has been made of the new mantra in Washington these days, of balancing the budget within the next seven years, whether via the Contract with America or through reinventing government, it is the case that domestic discretionary spending, and therefore spending on research in education and federal support of our institutions, is at great risk.

I should point out the states are also in serious trouble, not simply from cost-shifting from unfunded mandates from federal government, Medicare, Medicaid, ADA, occupational safety and health, and so forth, but because of the effort to deal with K-12 education concerns. Many states have actually earmarked off the top the funding of those, and they've made massive investments in corrections in order to respond to public concerns about crime.

Well, one of my colleagues pointed out that a decade ago, when I assumed the presidency of the University of Michigan, my state had 15 public universities and eight prisons. Today, we still have 15 public universities but 35 prisons. And this past year, the amount we spent on corrections in our state, about \$1,500,000, passed the amount we spent on higher education. That's happened in many other states, including the state of California. It raises, in a very real sense as well, whether we are increasingly beginning to regard education as a private good rather than a public good – moving away from the public principle that since education benefits all of society, all of society should support it.

A related concern, having to do with dollars but also with regulation that university presidents at institutions like this have to worry about, has to do with the rock and the hard place. In the life of many university presidents, the rock is intercollegiate athletics. The hard place is the medical center.

The great deal of time and attention is focused on how to help these extraordinarily valuable enterprises survive in a world in which health care delivery has shifted cost from third party payers to hospitals and now directly to doctors – that means to our medical school faculty.

The third concern: forcing change is politics itself. Across this nation, we're seeing once again an effort, sometimes well-motivated, sometimes quite misguided, by politicians to influence everything involving our universities, from the prices they charge to what they teach to who teaches to whom they teach. We see that in federal policies. We see that at the state level.

But I think what's the most concern of all is that in our society today there seems to be a new brand of politics – indeed, I might say populism – abroad, almost a post-modernist, deconstructionist variety that not only challenges but actually tries to destroy social institutions and social commitments. I think of the effort made in the state of California today to unravel three decades of support of affirmative action, which is now appearing in most states across this country.

Related to that are the particular pressures on a university presidency. A week ago, the Association of Governing Boards (of Universities and Colleges) released a major report of the

National Commission on the Academic Presidency, which concludes that the greatest danger to higher education today is that, in an era of growing doubts and demands, colleges and universities are neither as nimble nor as adaptable as times require.

Why? Because the academic presidency has become weak – "anemic" was the term they used – the authority of university presidents having been undercut by trustees, by faculty members, by political leaders, and, at times, by the president's own lack of assertiveness and willingness to take risks for change. I think the fact that right now the presidencies of the ten major public universities in this nation are open or will soon be open and are going to be dreadful to fill is a sign that we do have certain problems.

There are even more fundamental challenges forcing change on our campus. Our fundamental mission of creating, preserving, integrating, transmitting, and applying knowledge is not changing, but how we do each of those activities is changing very, very dramatically, driven by other changes in our society. The pace, the nature of change, is so fast at times that we have trouble recognizing what's really driving us.

It could very well be that our present institutions, our structures for the conduct of intellectual pursuit such as research, are as obsolete and as irrelevant to our future as the American corporation of the 1950s is. I love the quote by Don Langenberg, chancellor of the University of Maryland, who said, "it is probably about as safe to assume that the dominant higher education institutions of the 21st century will stem from the small but powerful group of present day institutions," referring to the research universities, "as it would have been to assume that today's dominant life form on Earth would stem from Tyrannosaurus Rex."

What is the university of the future? How are these forces going to force change? Well, let me just throw out several possibilities. It is clear that our institutions, at least our faculty, are quite nimble and are already beginning to redirect their efforts. They're moving increasingly away from the public sector to the private sector for support. Beyond seeking corporate support for R&D, they're beginning to market far more aggressively educational services and put into place far more realistic price structures.

Beyond that, there are fundamental changes occurring. The American research university was a faculty-centered culture. After all, the faculty was the source of the research that drove the intellectual vitality of the institutions. Today, however, we're moving from provider-centered to customer- and market-centered institutions, to use a business term. In a sense, to enterprises in which the people whom you serve come front and center as driving the institution.

But there's an even more subtle shift that I believe is occurring, a shift in public attitudes now underway, placing less stress on values such as excellence and elitism and more emphasis on the provision of cost-competitive, high-quality services. That is, shifting from prestige-driven to market-driven philosophies.

This relates very much to *Science: The Endless Frontier* and the partnership it represents, because, in a partnership with relatively unconstrained patronage, to get the highest quality

research, you provided that patronage to the highest quality faculty, to the most prestigious institutions. Academic excellence and prestige were valued.

Today, society seems reluctant to make such long-term investments. Rather, it seems interested in seeking short-term services from universities. Of high quality, to be sure, but with cost as a consideration. In a sense, it's shifting away from value and prestige in an effort to seek low-cost, quality services. That is, it's asking, "If a Ford will do, why do we want to buy a Cadillac?"

That suggests that the research university as we know it today, rather than moving into some new paradigm, may in fact return to a paradigm of the past, a century ago, with institutions, such as the land-grant universities that tended to focus much more on responding to the here and now needs of American society.

What drives this is a very interesting feature of the American university that most realize once they think about it but is rarely discussed. The modern university is a holding company for entrepreneurs. In a sense, we are indeed a collection of highly entrepreneurial, highly talented, and driven faculty members, each of whom is trying to optimize their own particular objectives and move toward that – and that, in turn, drives the evolution of the university.

That's why my university, for example, has become a \$3,000,000,000 a year conglomerate. We do teach 50,000 students a year, but we also treat over 1,000,000 patients a year. We have campuses from Seoul to Hong Kong to Paris to London. We're too big to purchase insurance, so we run our own insurance companies. We have a big-time entertainment industry called the Michigan Wolverines, which generates about \$280,000,000 a year worth of licensing.

What does that have to do with the core learning of the university? Well, it's sometimes hard to find the relationship, but that's what we've become. A highly adaptable knowledge conglomerate. And I would dare say most of our research universities have become the same. Driven by the interests and the efforts of our faculty because we've provided them with the freedom, the encouragement, and the incentives to move toward their personal goals.

It's that point I would like to conclude with, because I believe, having been a part of it, having essentially grown up in it, that the American research university is probably more important to our society and our world today than ever before. I'll simply remind you of a statement made by Erich Bloch a number of years ago, when he was director of the National Science Foundation, in testimony, that the solutions to virtually all the problems with which government is concerned – health, education, environment, energy, urban development, international relationships, space, economic competitiveness, defense and national security – depend on creating new knowledge and hence upon the health of America's research universities.

As important as these institutions are in our everyday lives today, it seems increasingly clear that, in the future, they should play an even more critical role. And yet, even as I speak, our institutions are evolving away from that particular paradigm.

The individualistic, entrepreneurial nature of our faculty, the fact that they do sense the pressures of our society, is moving them in new directions. They hear loud and clear the message that

America no longer believes in the importance of basic research and questions even the relevance of the research university. Whether they like it or not, the faculty is remarkably sensitive to the criticisms voiced by critics of the academy about too much emphasis on research. About too many Ph.D.s and not enough jobs. About whether we should shift towards more applied activities.

And they are responding quite rapidly to adapt to this brave, new world. I, for one, fear that unless we sound the wake-up call not simply to America but to sound it sufficiently loud and clear that our faculty can also hear the reverberations, the American research university will already have evolved into something else. Perhaps responding to other societal needs, but no longer with the capacity to respond to the intellectual needs of this nation and society.

The world and the structure of academic research have changed a great deal since this report and the principle was put out. But those principles, I think, still merit re-affirmation. Now, more than ever, the national interest calls for an investment in human and intellectual capital. In a sense, that's our challenge. To continue to make that commitment. To provide that, even during a time of extraordinary change. Thank you very much.

COLE: Thank you very much, Jim. I'm sure there will be a lot of people who will want to not only comment but ask questions on that. We will now shift over to the comments of our second policy design presenter. And it's a personal privilege to introduce Donald Kennedy, who is currently the Bing Professor of Environmental Science and president emeritus at Stanford University. His research interests originally were in animal behavior and neural biology, in particular, the mechanisms by which animals generate and control pattern/motor output.

In 1977, Don Kennedy took a two-and-a-half-year leave to serve as commissioner of the U.S. Food and Drug Administration. Following his return to Stanford in 1979, Dr. Kennedy served for a year as provost and for 12 years as president, a time marked by renewed attention to undergraduate education and student commitment to public service and successful completion of the largest capital campaign in the history of higher education.

As I think about the Bush period and the aftermath, the 50-year period since the publication of this report, there are a number of American universities, both public and private – two of which are represented here in the panel today – that have made extraordinary, extraordinary strides. And Stanford has become, as we all know, one of the great, great institutions in the world of higher education.

I think Stanford and the country owe a great debt to Don Kennedy for being one of the real leaders in that growth and development. So it is great pleasure to have Don here today to comment and to present on this issue. Don? (applause)

KENNEDY: *Science: the Endless Frontier* as metaphor represents a momentous decision that decanted the mechanism and the resources for supporting science into the institutions responsible for training the next generation of scientists. It was a bold step that no other industrial democracy took, and the others have reason to regret their choice. There is no question that the

decision was good for science. The question I want to consider is, was it also good for the universities? That is a harder question.

It may not be the right moment to answer it, because for America's universities it is not unfair to say that it is the best of times, it is the worst of times. Surely it is the best in a number of important respects: scientific vigor, desirability, international respect, and others. But it is also the worst of times, and for a whole array of reasons. This awkward sense of doing better but feeling worse resonates with a historic public ambivalence about higher education. On the one hand, we are the escalator of upward mobility and the agent of personal improvement. On the other, we are seen as elitist and stuck up.

Our public, while clamoring for their sons and daughters to get accepted, resents the fact that in little more than a decade the lifetime earnings gap between high school and college graduates has increased by 50 percent. Our research accomplishments are recounted breathlessly in the newspapers, but in conversations among parents, the central theme is that Susie's calculus teacher can't speak English as well as Susie. Some of this disaffection is aimed at a utilitarian academic research culture that in some ways is a collateral descendant of *Science: the Endless Frontier*.

That report introduced a new role for America's universities. As keepers of the national scientific flame, they came to be seen also as the driving force for a whole suite of economic and social objectives. At first it was the general argument that basic research would empower a more innovative society. By the late 1970s, international competitiveness was already being invoked as a challenge for university science and as an argument for funding it more generously. By the 1980s, higher education was being seen as an engine for improving regional economies. And every valley with a university in it seemed to be made of silicon.

Somehow, though, the American public has held on to a more distant version of the university: one that today sounds almost quaint. It is a place where young people get in touch with great ideas through introductions conducted with sympathy and understanding by thoughtful older scholars. It is a place where they learn to analyze and reason, and develop the habits of inquiry. It is a place where intellects can wander freely over ground that may or may not have immediate application, but where the culture is examined and advanced.

At the core of this image is the passage not just of knowledge but of the capacity to gain more knowledge from one generation to the next. When Americans look at their universities, they sense that the new utilitarian obligations have somehow triumphed over this older and deeper vision. That disparity, the gulf between new reality and old expectation, lies at the heart of our present public discontent.

In what follows, I want to try to map that more precisely. But lest the rest of this seem too discouraged or critical, let me begin with a quick accounting of the benefits that *Science: the Endless Frontier* has left with American universities. They are boundless.

First, doctoral training has been made richer and more effective, to the benefit of science and, presumably, to the benefit of the trainees as well. Revenue accruing to the universities from

sponsored research has not only made possible a new level of intellectual activity in scientific fields, it has permitted internal reallocations that have helped the non-scientific disciplines as well. Educational programs generally have been enriched by closer contact with active investigation: not only graduate students but undergraduates have been the beneficiaries of new opportunities for well-equipped independent study. There has been a closer coupling between university research and societal need. Support from federal mission agencies and from industry has extended the domain of research application. It has helped to keep faculty closer to the most dynamic locus of research activity, and in that way has enriched teaching at all levels.

But in other respects, the very success of the idea Bush launched has, as so often happens, produced some second order problems. First, the postwar research surge has altered the balance both between undergraduate and graduate education and between research and teaching. Although in some respects there has been expanded opportunity for engaging in supervised research, and undergraduates have benefited from the change in those ways, their greater distance from faculty and the absorption of the latter in their own work has probably weakened the undergraduate experience. Undergraduates spend far more time today with para-faculty and teaching assistants, and less with senior faculty.

Second, the expanded opportunity for graduate students in their own specific research areas has been accompanied by some real restriction of opportunity. The growth of research assistantships and the lengthening of time required to complete the doctorate are side effects of the need for graduate students as labor in the university research enterprise.

Perhaps this need accounts for the unwillingness of our science departments to limit graduate enrollments even in the face of evident oversupply. This is a tragedy of the commons that is producing a morale crisis for some of our best and brightest young people. If you want to glimpse the depth of this discontent, talk to doctoral candidates at west coast universities who refer to the "I-5 route," the series of substitute teaching assignments they may be forced to take at the several dozen institutions spread along the Interstate 5 corridor.

There is a litmus test for detecting when sectoral problems assume enough significance to begin the transition into publicly recognized issues, and it happened to this one: Garry Trudeau made it a long-running theme for *Doonesbury*. The agent of President King is outside the gates of Walden College recruiting gypsy faculty from an eager crowd of candidates assembled there in a mob. He's shouting through a bullhorn. "Intro Bio. I'm looking for an Intro Bio." A well-dressed respondent says, "I'm a Cornell Ph.D. I don't expect tenure, obviously, but I would like a two-year contract with medical benefits." The agent looks around, then asks, "Any other candidates?" From the back, "I'll work for food."

The crisis of confidence is made worse by a disjunction between what the students are trained to expect and what they are likely to get. Little or no effort is made to prepare our doctoral candidates in the sciences for alternative careers, or to be more effective teachers, or even to confront some of the professional and personal challenges – ethical and other – that they may meet in academic careers. We do more for MBA and law students in this regard than we are doing for those whom we are preparing for our own profession. It is extraordinary.

In fact, our graduate students are being prepared to lead lives exactly like those of their research supervisors, and for that only. Naturally, they expect they will find work in elite universities. They are almost invariably disappointed.

The growth of dependence on federal funds among state-supported as well as private research universities has blurred the distinction between public and private. The University of Michigan and Stanford might both be described as quite similar federal universities. This blurring has been accompanied by a subtle but steady increase in government ambitions for control, which are justified under the all-purpose principle of accountability. In the past ten years, government agencies have made determined efforts to regulate access by particular groups to unclassified university research; restrict access of foreign nationals; place restrictions over academic researchers publishing their own data; and pursue newly-claimed regulatory authority over something vaguely defined as academic misconduct. We have also watched the growth of legislative pork-barrel appropriations.

I am not suggesting that universities should do no government work or take no government money, but we need to be realistic. When institutions serve utilitarian purposes, they invite political intervention. Absent the growth in federal control we have seen, I suspect that state university governing boards might not have become as ambitious as they have, and might have stayed in their traditional oversight roles.

Today, three great public university systems – Michigan, California, and Minnesota – are in desperate disarray over efforts by political regents to assert control over traditional academic functions. It is a very serious situation, so far without significant opposition or public outcry.

The success of the research venture, spectacular though it has been in many respects, has been mixed. Where there are small production units and tightly bounded problems, the returns have been extraordinary. Perhaps the success of biomedicine is the best example.

For the big problems that societies have to solve – violence, poverty, environmental deterioration, the economics of health care – university research has been much less successful. I suspect that two explanations for this may be valid. One is that the funding system has strengthened departments, making interdisciplinary work more difficult. The other is that the very system of making grants defines areas too tightly.

Finally, the legacy of *Science: the Endless Frontier* has been to alter life irreversibly for faculty members, especially in the sciences. The new order has added immeasurably to their productive capacity, but it has also attenuated their institutional loyalty. Faculty are more peripatetic. Their membership in the invisible international academies of their disciplines is far more weighty in their lives than their attachment to their own university and their students. It is this disengagement that caused Henry Rosovsky, concluding his second term as Dean of the Faculty of Arts and Sciences at Harvard, to speak of the secular decline in civic consciousness of his distinguished professorate.

Now I return to the problem of the American public's troublesome disaffection with higher education. First I will summarize it, then suggest some resolutions. The problem is that we are

seen as not occupying a central role in solving the big problems, as overbalanced in our emphasis on esoteric research, and worst of all, as failing in our duty to educate our sons and daughters. In short, even considering the benefits we have gained in the past 50 years, we need to worry about the costs.

Can those costs be reduced without giving up the benefits? I think that the resolution depends, in the end, on a pretty simple principle that rests on a notion about intergenerational equity, a notion very much built into the Bush proposition as it was originally put: we need to return students to the center of our institutional concern.

The argument for this is not a kind of moral abstraction, it is intensely practical. It is very difficult for me to think of an academic scientist, even among the most distinguished colleagues I have had, who has not contributed more through the students he or she has produced than through his or her own work.

That is how we progress: by finding people with capacities greater than our own, filling them partway with what we have to offer, and then watching them go off and go farther than we have been able to do. They, more than the innovations begun in the labs where they were trained, are the mainstream of technology transfer.

It is people, not things. In practical terms, shifting our gaze does not require a disengagement from research. But it does require abandoning the idea that advanced students are there primarily to serve contemporary ongoing research programs. On the contrary, they are there to develop their own capacities, which they will do best if permitted much more choice and control, and given a broader education than is now the case in most university science departments.

William James once referred to the Ph.D. octopus. Times haven't changed much. We are requiring a degree well-designed for one set of things, giving it to people, and watching them go out and do another set of things. It is remarkable to me how we could have gotten into the situation we have with respect to the market crisis our graduates are confronting.

In the 1960s and early 1970s, those of us with active research programs thought we could turn out a Ph.D. every year or two, totaling up to maybe 15 or 20 over a long career. Did we really think that this employment sector was going to increase by 2000 percent in one generation? Had you posed that question then, anybody would have said, "of course not."

We created that excess with the encouragement and enthusiastic support of government policies and funds. Now we have to rethink our rate of production. One of the difficulties is that replacement is happening too slowly. Universities are in a kind of academic gridlock in which resource constraints and retirement disincentives are combining to block a generational transition. That is unfortunate, because the young people who are surviving this experience and getting the few positions that are available in the research universities are extraordinary. They are the best we have ever seen.

That brings me to a concluding recommendation. The most promising route to constructive institutional change is, in fact, to change the players. We are confronting an alarming problem in

an aging science faculty that will not quit. In the past two decades, the average age of faculties of most research universities has increased by somewhere between six and eight years.

I promised you another meaning for the endless frontier metaphor. It is this: my cohort of academic scientists, this group of aging buckaroos, has been riding through the golden age of the frontier. We have passed through the fence that was called mandatory retirement until the Congress busted it, and we're headin' for the sunset, defined contribution retirement plans in hand. There's every incentive to stay in the saddle. So happy trails, partners. The frontier may be endless in more ways than one.

To rescue our successors from discouragement and broaden the influence of science in the larger society, we need to change graduate education for our best students. We need to open up some different opportunities for the very good others. Above all, we need to put the next generation at the center of our concern. And the best thing we may be able to do for 'em, partners, is to get out of the way.

COLE: Paul David is our first panelist and also one of the extraordinary contributors to issues of science policy. Paul is professor of economics at Stanford and, since 1994, a senior research fellow at All Souls College at Oxford. Dr. David is known internationally for his contributions in a variety of fields, including economic history, economic and historical demography, and the economics of science and technology. I can tell you personally that I have spent time exchanging ideas with him. And hopefully someday Dr. David and I will get to collaborate on some work that we are doing that is very similar. So it's a great pleasure to have Paul David here as the first panelist in this session. Paul?

DAVID: (applause) Thank you very much, Jonathan. I accept the offer of collaboration.

The billing of these sessions as design sessions put me in mind – especially after listening to our distinguished presenters who have been through the fire of recent developments in American research universities – of the problems of designing the future of a transatlantic transport system from the deck of the Titanic. There is some need, in the midst of the scramble for the lifeboats and attempts to figure out where the nearest landfall might be, to maintain some perspective on the larger set of questions.

And what I want to do is to comment on the context within which the problems of the American research universities might be considered. To look at some of the system-level implications of the possible remedies that are being suggested for the problems and future of the research universities. And to suggest that, in the spirit of the remarks of both Don Kennedy and President Duderstadt, there is a set of unique roles that the universities have played and are uniquely positioned to continue to play. And those roles are becoming potentially more important for national well being, even at the time when the ability to perform these roles is increasingly under challenge. And one needs to think about the ways in which the universities can do what they uniquely are able to do, rather than transform themselves into some other kind of institution.

The first point of perspective that I want to insist on is that, when we talk about the universities and research universities, we ought not to be thinking only about the 60 universities that form the

upper quintile, the 20% of the research universities. There are about 200 research universities. The upper 20 percent, it's true, do about 50% of the total research and something between 50% and 60% of federally funded research. Within this top half, there has been a history of increasing spread of the research-style university over the course of the past three decades.

And we can ask, what was the logic that drove an increasing number of institutions of higher education to get into the research mode? And by reflection, we can ask, what will be the implications of an alteration of the environment? Where will the pressures for change be greatest, and where will the alteration, the readjustments be most dislodging for the larger university and non-university research system?

When we look at the fiscal pressure, the cuts in public funding that are being scheduled, it's important to bear in mind a point that has frequently been touched upon. And that is, we do not have a consolidated research budget. The nature of the cuts is a function of what's happening in a number of diverse agencies, which are responding in different ways to cuts of different magnitudes.

And therefore, if we look at the pressures that have been felt in the Department of Defense and the Department of Energy, it's important to note that relative to the other major funding agencies of NIH and NSF, those two agencies were most elitist in their approach to funding. They had specific missions. They had a need to fund research to achieve a certain research product. The effect of cutbacks in that section tended to impinge particularly on the upper echelon of the research establishment. And other agencies, such as NSF— which has an explicit mission to build up a very broad-based research establishment – have tended in the face of cutbacks to spread these out across the whole system. To maintain for various reasons some political protection, because of the nature of their mission. And to maintain continuing research activity even at a lower level across a much wider range of institutions.

Now, the effect of that difference has been that the agencies have tended to increasingly at the margin ask the universities to bear the cost of some of the research. And the effect of that has been, as many people are aware, to reduce the effective ability of the system to cross-subsidize a wider range of activities, including teaching.

Research cross-subsidized the growth of a large part of the university system and, to a large extent, was an unexpected byproduct of the approach which Vannevar Bush foresaw – an indirect cost aspect to the funding of research that would put resources at the hands of research performers to be used for a wider range of activities.

The shift from a patronage mode to a procurement mode has led to the abandonment of that implicit contract. As a result, one of the things that's happening at the margin is that the effective amount of indirect cost recovery has contracted. A recent set of estimates suggests that, although the average negotiated cost recovery rate is something like 50% or 48%, the actual rate for private universities is 30% and for the state universities is 20%.

Over the course of the '80s, the universities responded to this by using indirect cost recovery to stay in the research business by matching these federal funds. And the result has been the

disappearance of effective margin for the support of a wider range of university activities. It is in that context, it seems to me, that the set of pressures for redirecting the activities of the elite universities back towards teaching acquire a greater force and a greater appeal, because the former fiscal complementarity between teaching and research has disappeared.

There was an important set of organizational, intellectual, and pedagogical reasons for the coupling of research and teaching. And I think we have a general agreement that those arguments still obtain. And they obtain particularly strongly at the level of graduate teaching in the sciences. This goes without any dispute, certainly in this audience.

But what has happened is that the generalization of the research-teaching complementarity as an institution-building strategy, as an organizational strategy, as an internal fiscal strategy, has disappeared. And the question I want to raise is the extent to which the fiscal decoupling of research and teaching goes into a steady-state first and then contracts – and what can be done to prevent that from being translated into an intellectual and organizational decoupling of teaching from research.

I think that we need continually to understand the larger systemic implications of allowing such a decoupling and of allowing a reorientation of major institutions of higher education away from the performance of research. Because the implications of such decoupling are potentially very serious not only for the universities but also for society at large. There are three areas of dysfunctionality that I think we should bear in mind.

One concerns the implications for the research activity in the national research system. The second has to do with the implications for the training of future generations of researchers. And the third has to do with the ability of universities to fulfill their role as open nodes in a international global knowledge production and knowledge exchange system.

And the spirit of all of these points, it seems to me, lies very close to the set of concerns that Vannevar Bush had in mind when he proposed that the university should be a vehicle for an expansion of research activities to replenish a stock of knowledge that had been drawn down, as he saw it, rapidly in the war mobilization efforts.

There are three archetypal issues. The first of these is, what portion of public funding of science and technology should go to research that is driven by the internal logic of the subject – that is, the development of conceptual schemes for their own sake?

This is not a question encountered only in the public sphere. There are some large R&D-intensive business corporations that also have sufficient resources to make it pertinent for them in their strategic planning.

But research is an uncertain proposition, as we know. And such planning is insufficient to dispose of the underlying issue completely. Many important fundamental science advances have derived from problems that were first encountered not in a blue sky or curiosity-driven program but in practical research contexts.

And so the second practical choice point in the management of research is to ask how far beyond the immediate need for a solution to a problem at hand, a particular research mission, should you encourage researchers to go in exploring the more general conceptual problems that they've opened up – thereby creating potentially new demands for curiosity-driven research that otherwise would not have been discovered and couldn't be planned exactly.

One microlevel form at which this second practical matter occurs is how tightly specified is the budget. How close does it look to the grant, to the procurement contract?

We're living increasingly in a mode in which pressures on the universities from funding agencies – in particular the federal government but also to some extent in business collaborative research – have resulted in what might be called grant tracts.

A grant tract is half a grant and half a contract. It has a short term. It has deliverables. It has a lot of monitoring and regulation. It prevents mid-course corrections in research projects. It prevents people going off and chasing things that weren't in the original work plan.

So the issue is how much top-down as opposed to bottom-up research direction there is going to be. The traditional university mode allowed within the context of grants an enormous amount of flexibility and chasing things that were not ordinarily planned. And one can say that in the system as a whole, you want to have some of that. And you don't want to see all of that go away.

The third choice point involves the question of what is to be done with the findings. The opening up of a new demand for investigation by seizing on the accidents of research often entails the mobilization of concepts, research talents, and techniques imported into new and emerging fields from areas whose relevance was not immediately perceived.

We can think of laser science and its applications in microsurgery or molecular protein chemistry in relationship to plant genetics. Computer science in relationship to gene sequencing. A different range of questions, thus, is posed.

We want to ask how widely, how quickly, are the findings of research in a new area going to be disclosed. How fully are they to be disclosed? Who is to have access to the data? And at what levels of completeness? How should the new fields be best explored? By complete disclosure, which throws it open to all commerce on an equal footing, or by policies of information management designed to keep direction control in the hands of the original discoverers? Or the institutions supporting them?

This is the important issue of access and openness in science that was quite central in Bush's thinking. It remains very central. But it is increasingly under pressure.

If one considers the pressures to adapt to new sources of funding within the university, one can look back over the 1980s and see what has been nicely documented in a Ford Foundation-financed study carried out by Wes Cohen, Richard Florida, and Richard Go, all of Carnegie Mellon, who looked at the growth of university-industry research centers. We did not have a national industrial policy. We did not think about it. The Reagan administration foreswore

having an industrial research policy. And nonetheless, encouraged by the administration, the number of university-industry collaborative research centers expanded rapidly. And now there are more than a thousand of them, spending in 1990 approximately \$2.5 billion on R&D and another \$1.6 billion on research-related activities, including education and training.

The one area of the Cohen-Florida-Go report on which I want to draw in this connection is one that concerns the changes in policies towards openness of information within these units. Nominally, they look like university activities if you ask about their internal and fiscal management. Between 88% and 91% say that industry has little or no influence over their fiscal management or their internal administrative operations.

But if you ask what has happened to the norms regarding control of information within these organizations, you see that at first subtle and then not so subtle changes have taken place. If we ask in what fraction of these institutions are participating companies allowed to restrict the flow of information both inside and outside the centers in which they are involved, you find that in 57% of these units in the sample, the firms have information control policies that permit restrictions. In 53%, communication of information about research projects to non-participating companies was not permitted. Well, we think, okay, this is reasonable. We don't want so much free riding. In 40% of the centers, information flows to participating companies were restricted even if they were not involved in a particular project.

Now we want, at a lower level, to enforce collaboration in particular projects if you want to have full access. Now if you ask about indirect leakage via the academic research communities, you find that these centers also have in place restrictions to prevent that. In approximately 29%, there are restrictions on communications with faculty members at large. In 21%, communications with faculty of the center's own university was restricted. And in about 13%, there were internal restrictions on information flows to faculty working within the center itself.

One more point might be made about this. If one asks about the effect on permitting delays in publication, I think we are quite familiar with the fact that most universities have now allowed for delays to allow time for patenting. In many cases, the offices of technology licensing are themselves the patenting entities. But what about suppression of research results? I found it very startling that in 54% of the institutions, when the mission was regarded as very important to the company who was sponsoring it, they were allowed to suppress research results. In 20% of the centers, firms were allowed to suppress research results whether it was important or not. Thus, in a substantial number of these centers, we have a reversal of the prior norms of open research and their supplantation by essentially the rules of proprietary research.

Now, what these developments portend, at least for me, is the prospect that if one moves towards the decoupling of research into affiliated institutes and separates the teaching and research from the general context of the university, one can predict that the alternative system of incentives and norms regarding scientific cooperation and disinterestedness and openness in research will be supplanted by the other system through which research is organized. That is, we will move from the system of relationships among researchers and their views about information that characterize a patronage system, in which there is the implicit bargain of patronage in exchange for full disclosure, making into a public good new knowledge. The whole system of production

of reliable knowledge as a collective distributed process will be replaced by the alternative system, which is a property system.

That is, you have intellectual property. You are rewarded by being given an element of monopoly power over the exploitation of knowledge – and therefore have incentives to keep it private or semi-private until you can secure full property rights or to use secrecy as the alternative means to appropriate the benefits.

For me, a problem in research management is to get the balance between these two modes correct. We have a system in which we have managed to balance a very large and active industrial research activity with a very vibrant research activity conducted under the open science mode through the universities.

If we allow the pressures of the vice within which the universities have been placed – between the cutbacks of the agencies and the pressures of OMB and other organizations to make them lean competitors – lead to the shucking off, the shedding of research activities into semi-independent organizations, because they are no longer a source for cross-subsidization of the other missions of the university, than this decoupling will have a serious impact upon national research activity.

It will affect not only the character of the research but also the character of the training and the ability of the universities to provide to industry the enormous subsidy it provides through the training and evaluation of researchers. It's true that university professors are producing graduate student Ph.D.s like sunfish, at a rate of about one to fifteen (that's approximately their lifetime reproduction rate) faculty members per university Ph.D.s in science and engineering. But these Ph.D.s do not have to be, and have not historically been contained, within the university system. They move into industry. Since we are also a specialist in training people in this system from overseas, they also move out of the country.

Our ability to train people in an open science mode to carry on this kind of research has had important effects on the attitudes of firms in the industrial sector. There are large firms – and I'm talking not only about Bell Labs or the IBM campus or Xerox Park, all organizations from which enormous technical advances have flowed – that conduct research and publish their research in order to stay in touch with the open science mode.

And then when that goes, there will be consequent changes in the style of research carried on in the corporate sector. And the effects of this I think are deleterious. They will also lead to changes in the ability of American researchers to interact on an open basis with research in the rest of the world at a time when people recognize that increasingly the science base is internationally distributed. That there are lots of areas where the expertise at the frontier needs to be tapped in order to absorb knowledge for application and for furthering research in this country.

So while I believe that the major universities have to think about their core missions, and that their core missions include teaching, and that one can take the redirection back towards a concern for teaching as an important set of pressures to which the universities must attend, it is equally important to keep in mind that those needs and that part of the university's mission was

always important. That the arguments for being more attentive to our undergraduates and to the needs of graduate students to develop their own autonomy as researchers and to be able to pursue a career are significant.

We are being tempted to decouple research as competitive with those goals – not because they are necessarily competitive from a pedagogical viewpoint, not because they're competitive intellectually, but because the complementarity on the financial side has disappeared. And it's important not to be driven by that into a decoupling of research from the other modes of the universities, which will be both damaging for the students and damaging for a much larger set of concerns nationally.

I think the universities have to think about their other important mission, which is to be centers of open learning. To be the points of contact with the international open science network. That universities should be perhaps less worried about lack of civic loyalty and more interested in collaboration and in reducing research costs by shared access to facilities.

We have an increasing number of tools through the information revolution that will permit remote access, sharing of facilities, tighter coalitions among universities both nationally and internationally. And the American research universities, given their present position in the world, are in a unique position to exploit this. That is the direction a healthy set of responses might go along, taking the point that we also need to consider the origins of the university institution as a teaching vehicle. Thank you. (applause)

COLE: Thank you, Paul. Our second panelist is Eduardo Macagno, who as an undergraduate worked on the team with Professor James Van Allen on the early exploration of the earth's radiation belt. He began his studies in the physics department, actually at Columbia in 1963. He has now become the dean of the Graduate School of Arts and Sciences at Columbia, appointed to that position in 1993 by George Rupp when he assumed the presidency. And he holds a co-title of associate vice president for research in graduate education. Also, he made a shift from physics into neurobiology after studying in the post-doctoral position with Cyrus Levinthal of Columbia's department of biological sciences. It's a great pleasure to have Eduardo here this morning as our second panelist. Eduardo?

MACAGNO: Good morning. I'd like to offer a few reflections on issues that have been raised both by my fellow speakers this morning and by others at this conference and elsewhere, as they relate principally to my current interests.

I would like to reflect on some issues, principally as they relate to graduate training and its role in research, that I have to deal with as both the dean and as a scientist with the laboratory that is still quite active. There are certain contradictions that I face almost daily between the two things I'm trying to do, and I thought I might bring some of those up.

As opposed to the more general views of my fellow speakers, I'm going to try to deal with more short-term concerns. To quote a favorite saying of my colleague Jonathan Cole, "The devil is in the details." I think we need to think in those terms about what kinds of things we might be doing to move towards the future. I think our system of coupling of doctoral training with research and

also of projects that are proposed and carried out principally through faculty-initiated, individual-initiated grant proposals, has many things that are very positive and need to be remembered. But there are a number of problems that arise, inevitably, from the system.

As has been pointed out by the previous speakers, the system is fundamentally dependent, as we've conceived it in the past, on an ever-expanding base of resources and positions. The faculty trains many Ph.D.s. The number of scientists clamoring for opportunities increases exponentially. It is not surprising, therefore, that the competition for grants has become fierce and that hundreds of applications are received for each faculty position that is advertised.

It has been proposed that we practice birth control by limiting the number of Ph.D.s we train as some professions, in fact, have done with their own degrees, with their own production. And some departments, in fact, have begun to reduce the size of the graduate programs. But I think there are some significant problems with doing. As has also been pointed out before, who is going to do the research that is now performed by graduate research assistants if we reduce the number of students going through the pipeline? Certainly, one possibility is that post-docs and technicians do that, but of course that will cost more money.

I think one needs to consider as well as whether there is a supply of post-docs and technicians who can, in fact, do the work and in a creative way, like graduate students do it at this point. I think we need to rethink how we do research if, in fact, we move seriously away from that mode.

A second question that arises is, how do we select who gets into these programs? To paraphrase Dr. Gomory's unpredictability principle, we cannot predict who is not going to be a good scientist. We have an idea of who might turn out to be a great scientist. They're easy to recognize. The very few who are even as undergraduates extraordinary but whom we say no to is very hard to determine, and I'm not sure that we can.

Another question is, given the way that all the problems have been discussed so publicly, how do we keep the very best possible candidates for scientific careers from going into other careers? That is, by proposing that we are going to be very selective and reduce the size of our graduate program, I think we're also driving away potentially very good scientists from considering our program.

Our emphasis on individual-driven projects has also some negative consequences that we need to think about. For example, collaboration to reduce duplication and inefficiencies is hard to introduce. The faculty is used to operating very independently and to essentially having a great deal of hegemony over their own operations. I think that has translated, to some extent, at the federal agencies into a lack of funding for common facilities for supporting, for example, technicians that maintain equipment and so on.

It is not that difficult these days to get equipment for shared facilities. It's virtually impossible to get funding for the technical personnel who will keep those going. It was the case, 15 to 20 years ago, that the NIH provided a certain amount of general funds to a university that could be used for a variety of purposes, one of which was this. But as the funds have become somewhat less

adequate, the pressure to put all the funding into individually driven grants and proposals has, essentially, pushed towards the disappearance of such funds.

A point that I think is worth considering is that we have undervalued post-doctoral and research positions. In fact, in many publications, such positions are referred to as underemployment, because the tenure-track faculty position has become the supreme goal of the people we train.

Another issue worth discussing is that the system, as it has evolved, has led often to distrust and in fact conflict between university administrators and faculty. As I said at the beginning, I see that kind of conflict going on as a scientist, and as a dean I'm having to work in different directions at times. The faculty often feels that the overhead is excessive and that it should be maintained within their operations as opposed to being given to the university, because they feel that it cross-subsidizes too many things. The faculty feels that tuition that we charge for graduate students is unwarranted, because they are in fact in the lab and there should be no tuition paid. The administration suspects that the faculty is always trying to gain the system and keep all their money for themselves. This kind of interaction has had some bad consequences, which, I think, have repercussions outside of the university.

So, those are just a few ideas that have come up from discussion that I've heard thus far. I'd like to suggest a few possibilities for how we might deal with some of the problems that have been created by our system in the short term.

I'm not talking as much as the previous speakers about the long-term evolution of the university. As both the scientist and administrator, I'm trying to think of ways in which we might evolve in the short term, to deal with some of the problems that I just mentioned.

I think we need to reduce our dependence on graduate students for carrying out research, by shifting more to post-docs and technicians. And that requires that we improve both the status and benefits of post-doctoral trainees and professional researchers, who are in fact post-docs perhaps in a holding operation but maybe just in a situation that they'd like to be in. Of course, the status and the benefits are not commensurate with staying in that position for very long. If we reduce the number of graduate students, we have to at the same time make those positions better considered by both the individuals who have those positions and by the university itself

We have to focus on the training of Ph.D.s rather than on the output of the students as they do their research, by including more teaching opportunities as well as opportunities to broaden the range of expectations. If there's a lot of pressure to reduce the time to a degree, it's because it has at least in some areas gotten rather long. And so broadening the education should not mean increasing time to a degree by having minors or a lot of additional courses.

But we have to develop ways in which we can broaden both the interest and the expectations of our trainees. Internships in nonacademic positions are something that has been suggested by many and that we ought to look into. I think it is important for grants to provide some support of students while they are actually doing the research, but we've tended to depend too much on the grants too early on in the career of the student.

This, by the way, is exaggerated by the fact that lots of our students are foreign-born and cannot, in fact, be put on training grants. So, by and large, the support of the students who are also perhaps not capable of taking on a TA-ship (Teaching Assistant) has become a role for research grants.

Another proposal that I think we need to discuss is enhancing the value of master's degrees. As part and parcel of becoming more selective in whom we might admit to Ph.D. programs or in reducing the size of Ph.D. programs, we still need to perform our function within society of training the people who are going to go into industry and do their research in industry.

I have heard and I suspect that many of the jobs that our Ph.D.s take in industry could very well result from a master's degree rather than a Ph.D., although not across the board. So, the gradual decrease in the status and significance of the M.A. at the research universities has to be reversed. Those degrees, which are much shorter, much more flexible, have been a way of bringing in some revenue to the school. We have to make those degrees really be perceived as having both a status and a significance, better than they have at this point.

In a way, perhaps, the hardest problem is to get the faculty to change both their expectations and their set of values that they impart to graduate students. My own experience, here at Columbia, has been that by and large faculty is so directed in the sciences, towards the research, that educational questions are really rescinded. Not all – there are many sitting in the audience whom I recognize, who are very concerned about these matters – but many, particularly the lab scientists, are not willing to really change their way of thinking about their educational role. It is important for us to begin to bring them into this kind of discussion.

My next-to-last point has to do with an issue that you see in your programs. It is the moving, the separation, of education and research, which Dr. David has just raised in the context of the restriction of information flow. I think that we ought to fight this separation from another point of view, that students who end up doing their degrees in institutes, away from the campus, tend to have much narrower experience. It is much harder to give them the breadth that I think we need to give them. They don't interact with, for example, social scientists or humanists in thinking more broadly about the societal consequences and other issues of the work they're doing. They become too isolated. They also don't interact with other scientists in other disciplines.

You know, I've started an interdisciplinary seminar here. I'm finding a lot of trouble in bringing students who are in what I would call the institutes within Columbia – like Lamont-Doherty Earth Observatory and the medical school and even the Nevis Laboratories – to the university even every other week to have a discussion because they are so focused on their own endeavor within their laboratories and their disciplines. I think that it's detrimental to the vision that students have of their own opportunities and the issues that they should be thinking about.

In addition, separating graduate training and research from the undergraduate campus, at least from our experience here, would be very, very negative. A lot of the best undergraduates whom we can call away from the law, business, and medicine into the sciences come into the sciences because of that interaction with the research with the graduate students, with the professors. Even

if the interaction with the senior professors is more limited, it is not nonexistent. And there's a lot of enthusiasm for such careers, which is derived from that interaction.

My final point is, while all the issues about the evolution of the university that have been raised are important, I think we have to be careful not to overreact. I think oftentimes we see criticism as being adversarial, as opposed to being really a fundamental questioning, which we should welcome. I think the good things about the research university as conceived in *Science: The Endless Frontier*, as well as by its practitioners, the good things are there.

We have to make sure that in the process of considering utilitarianism or the economic drive or the fact that the university may change its conception vis-a-vis the society, we don't lose some of those wonderful aspects such as the interaction between research and training. Such as the openness of interactions and conversations that have made these places, the research universities, places that we all want to be in. Thank you. (applause)

COLE: Thank you, Eduardo. Please identify yourself as you raise the question or make a point.

GUSTON: I'm Dave Guston from Rutgers University. In Bush's day, the question was asked, "What is to be the federal role in funding university research?" One of the subtexts of that question that's missing here is the federal role as opposed to the state role and that was very important in that period.

There were three implicit arguments in *Science: The Endless Frontier* that favored a federal role as opposed to a state role. One, Bush thought there was a lack of sufficient talent to run research programs among the states. Second, the states lacked the ability to fund research in the university with stability over a long period of time. Third, the federal government would have to be less intrusive than the state governments would be apt to be.

And over the past 50 years, it's arguable that the states have become more talented, relative to where they were, and that the federal government has not proved so superior, at least in the current time, in not being obtrusive and being able to provide stable funding. So, not to jump on the devolutionary bandwagon, but the point is to suggest that maybe the argument for a federal role might be a little bit weaker in some respects now than it was 50 years ago. And the design question is, are there ways that we can creatively incorporate a new state role in university research that might expand the constituency for university research?

MALE VOICE: I guess that's the one I get. Actually, I think the point is well taken, if you go back a century. But I think it has some serious difficulties in 1996. A century ago, the states were actively involved in supporting highly applied research through agricultural experiment stations, through engineering experiment stations, that many land grant public universities have.

What has happened in the 1980s and 1990s, though, is the same structural budget imbalance that afflicts our federal government has also manifested itself at the state level, in which universities and their activities tend to be funded from a shrinking pool of discretionary resources with most of the real public revenue going into either entitlement programs, into corrections, into earmarked K-12, which limits their resources.

Second, there is very definitely a narrowing view of public support of universities at the state level, being used primarily for the support of undergraduate education. And, indeed, more and more states are moving towards formula funding, based on undergraduate instruction, which totally disregards the support of either graduate education or including in the professional schools and certainly research. And so I do not look with any great optimism to seeing the states play a significant role in the support of basic research on our campuses.

QUESTION: Just a quick addendum from a state more ambitious than most in trying to do things. The State of California has had a couple of modest research programs, funded by special initiatives. I think they have been poorly managed. I think that, you know, whatever bad things one can say about the federal bureaucracy, one can double in spades for state bureaucracies.

EISENBERGER: Peter Eisenberger, Columbia University. I guess what I find interesting in this discussion is that people talk as if there is such a thing as "the university" and there is such a thing as a single and simple definition for "education" and "research." What I'd like to suggest is that the enterprise has become much more complex than the original embodiment, as represented by how large it has become and the enhanced role it is playing in the society.

It might be helpful to leave the simpler models, where we start from the premise that there was such a thing or there is such a thing as a simple definition of the university, and think about the problem from the following perspective. On the education side, we are interested in educating citizens, we're interested in educating professionals, and we're also interested in educating future faculty members or intellectual leaders to join our academy. And on the research side, we want to certainly do research that is of value to society as well as research that pushes the frontiers of knowledge.

And if you take that complexity of possible missions and allow a diversity of institutions to arise that can specialize in meeting one or more of those missions, we might end up with a more robust enterprise than everybody trying to look like Harvard University, as I think the current system is trying to do. I raise that as a question, whether diversification is not an appropriate response and specialization is not an appropriate response to the current situation we are confronting.

MALE VOICE: Let me respond, briefly. Clearly, higher education in this country is highly diverse, although there is an unfortunate tendency to all look to mother Harvard as the model that they aspire to and intend to evolve in that direction.

I think part of the difficulty is that while there is good reason for diversity, unfortunately, we tend to send out signals and put out incentives that force some degree of narrowing of vision and expectations. I look at, for example, the single investigative grant paradigm, which has characterized the last 50 years, as creating this entrepreneurial university and destroying the concept of a community of scholars. I mean, in reality, research and teaching are both different variants of something we call learning. But unfortunately, we've created a system that puts very strong incentives out there that break it apart.

Maybe one of the issues that ought to be on the table is whether sponsors such as the federal government should make serious efforts to try and rebuild scholarly communities by shifting away from the traditional single or team grant approach to block grants, like it's done in many other countries. I do think this loss of a scholarly community is one of the great reasons for the problems that we have today.

MALE VOICE: If you're speaking about institutional diversity in the broadest sense, that's happening by itself, and it's healthy and it's terrific. We shouldn't, obviously, focus just on the research universities, except the topic of this conference put us in that pigeon hole.

If what you mean instead is what we were given in the case design, and I quote it here: "A case can be made that in a number of areas, there ought to be more of the decoupling between research and teaching, with research and perhaps advanced graduate education going on in specialized institutions with undergraduate and lower level graduate education, including in the sciences, going on at universities where the faculty may not be doing much research" – I think that's not a good strategy.

I think one of the benefits of the decision that we've been discussing here has been the extension of serious research opportunities to a wide range of undergraduate students whose talent may not have yet been recognized in their careers. We regularly recruit terrific students to the sciences and institutions like that. I'd regret the loss of that kind of opportunity, owing to a kind of premature segregation.

EISENBERGER: Just two quick comments. I really think that the thought of getting some institutional grants to help build community is something that should emerge from this exercise.

The second comment is, all I'm arguing is that we're trying to think about the problem from where we started, trying to make everything fit. It's just a logical construct I'm trying to address. That we're trying to approach the problem as if there's a single way of approaching it, rather than looking at the outcomes. We want to have students emerge who are not going to become academicians with a certain set of skills and abilities. We want different people to go into professions, and we want some people to come back and become faculty members.

And I'm just suggesting, if we ask what each one of those groups needs and then design a system to meet those needs, we might come up with a different answer than starting with a unified system and trying to stick them all into that same system.

MITCHELL: Hi. I'm Tyrone Mitchell. I'm with Corning, Incorporated. I have a very short question, but I have a long comment. (chuckle) I've been with Corning for close to six years now. Had a long career with General Electric. I'm a scientist by training, a Ph.D. in polymer chemistry from RPI.

I spent many years in the trenches working in industry doing product development, at General Electric, specifically, where I hold about 25 patents in various areas of technology. So, I'm really amazed at this conference. This is a very, very good conference. I'm really impressed with the credentials of everyone, all the speakers and the experience, the very broad range of experiences.

But my question is, where is industry's perspective at the conference? Now, I'm very much concerned about that. I work in a group called technology transfer for Corning, Incorporated, where we try to find new technologies for the science and technology organization. And I am the manager of technology assessment. In addition to that, I also monitor our interactions with universities. And one of the things I've tried to do is attend a lot of conferences where there's discussions about university-government-industry interactions, because any future research model has to include those three components. We are all here today because of one reason. That's because the Cold War ended, and the government is trying to figure out what to do with all of the resources it has.

Muddying the picture was the Bayh-Dole Act. We have run into a lot of problems at Corning in trying to work with universities because of that and the need for schools to own the intellectual property. Corning owns a lot of intellectual property, and a lot of these patents really aren't used. I think we need new models for how we're going to do science in the future.

Another thing I'd like to mention is that Corning was involved in a benchmarking that was done by some students from Cornell, where they did a project under a visiting professor who is a former vice president of Corning. That project was to study barriers to government-university-industry interactions. This happened out of the Cornell Business School, and these students in about three months did a very good study, comparable or maybe better than some studies I've seen that were done on the NSF grants that took a couple years.

I think the thing that made it work was the fact that these graduate students were pretty much turned loose on this. It was sponsored by Xerox, and they gave funds to these graduate students to travel all over the country, talk to different universities, different centers of excellence, different industries. And they wrote a tremendous report on some of the barriers to university-government interactions in technology transfer.

So, I think one of the models should include trying to get more use out of graduate students to do some of this policy making or determining exactly what the new policies are going to be. I think that model ought to come out of some of the graduate business schools, schools of economics.

I'll finish up by saying that recently I was part of transferring some new technology into Corning that came out of Los Alamos National Lab through a small company. I have to give a talk on that in a few weeks. One of the papers I came across pointed out that all of the fundamental understanding of that technology was done by two graduate students (one was an American graduate student and one was out of Japan), where the research professors just turned those students loose to go and do this work. They published some critical papers in the area, one in 1971 and the next in 1976. The technology was developed by a person out of Los Alamos. I guess it was around 1982 or '83 that he found these papers and developed this technology, which has started a small company that is doing quite well.

My point is, we really have to come up with some new models. You know, I've heard a lot of history today. I've heard a lot about what the problems are, but I think that there's some deeper thought needed, and we really need some innovation. Thank you very much.

MALE VOICE: Thank you for your comments. I do want to point out that later there will be a session that will be dealing with civilian technology policy. I hope that will address some of your concerns.

BERTZENBERG: Carol Hertzberg, Argonne National Laboratory. I'd like to speak to a point brought up by Donald Kennedy and I imagine some other members of the audience might want to also. And that is his suggestion that those of us in the older age group should retire and (chuckle) make space for the younger members of our profession to come on board and become active and take over positions. Great idea. Hard to effect.

A couple of points. Those of us who are scientists, most of us are doing it because we love science, irrespective of our condition. Nation of birth, race, age, gender, whatever, we love doing science. We don't want to give it up. There's another point, though, that is a little less obvious, probably to this audience, since I would imagine most people here are well to do. It probably isn't showing up too much in the universities. But it is showing up in other areas of our society. Scientists are no longer enabled to work as autonomously as was the case in the past. And salaries of many scientists are nowhere near what they expected when they entered graduate school. Many of you who have excellent positions at universities and industry and corporations probably don't feel this. But there are a lot of scientists out there who really feel the effects of this proletarianization. They can't afford to retire and let the younger generation in. This is not just a problem of this generation. But the way things are going, this is going to be a continuing problem of future generations. And I think we need to think about that.

MALE VOICE: Thank you very much. I'm not prepared to take names and to urge individuals to make this particular sacrifice. You would have every right to ask me about my own plans, which I will allude to briefly in a moment.

Let me tell you what I think the problem is. First of all, we do need to make arrangements so that academic and other scientists can have the opportunity to be intellectually active in retirement. Part of the problem is that we don't have an adequate set of arrangements for that.

The second problem is called defined contribution retirement programs. It was predicted that when people hit 70, despite the uncapping of mandatory retirement, they would take their pensions and go away. When they sharpened their pencils and started making the calculations, the actuarial advantage under a defined contribution retirement plan like TIAA-CREF (Teacher's Insurance Annuity Association – College Retirement Equities Fund) is overwhelming.

The result is that this past year, of the faculty members at major research universities who hit 70, in my sample over 50% are staying on past 70. That's a consequence of the design of retirement plans. We can't change the personal incentives to stay active. We can change the financial situation they encounter as they hit 70 or whatever.

GEIGER: Roger Geiger, Penn State University. I think that many of the pathologies that the speakers have alluded to are related to a single larger phenomenon. In the last 20 years, the research universities have performed approximately one-half of the nation's total basic research.

And they've done that not by expanding the kind of research that they were doing in the 1960s but by changing their research portfolio considerably. In other words, they've kept pace with the changes in the research frontier and the frontiers of advanced technology.

So my question to the speakers is, do they wish to continue, or do they wish to see universities cede a significant portion of the nation's basic research to other institutions, and probably cede some of their educational mission as well?

MALE VOICE: The comment I would make is one everybody seems to be stepping back away from for one reason or another.

The national labs are clearly struggling to find new missions at great risk as efforts are made to consolidate. I think most statistics governing industrial research labs indicate that the share of their activities devoted to basic research has dropped precipitously over the last ten or 15 years. Universities are one of the few games in town with respect to basic research. And if we pull back away from it, it's probably not going to happen – at least domestically. So in a sense, we do have that mission of great importance to the nation. And I don't think we can turn our back on it at this point.

Whether as we move into the future other kinds of entities will evolve in order to take up more of that, it's hard to say at this point. But I think there has to be a recognition that in the research enterprise in this country, the triad is already changing very, very significantly, making perhaps the role of research universities even more important for the future of the country.

MALE VOICE: I'll try and take a bite of that. I think it's clear that an implication of this question is whether the nature of the shift in the publicly funded research program is to continue towards mission-oriented, applications-oriented, near-commercial kinds of activities, sort of predevelopment but oriented towards that kind of work. And the question you have to ask is, is the university research environment one that is well-suited to that kind of research activity?

If the universities adapt to make themselves suited towards that, will it be possible to preserve the universities as the environment to perform a different kind of research? – more basic, fundamental, less top-down directed, more able to pursue different ideas and programs that arise possibly in an applications process but that lead into new directions and open up new areas.

There is a question as to whether within a given institution you can contain two essentially different and competing ways of organizing the research effort. I'm rather skeptical about that ability within one institution with one set of internal sets of incentives and priorities and research culture, one or another of which tends to dominate. And I don't think that you can maintain them in a healthy balance by doing both proprietary research and open research within the same four walls.

And so the question is, do we want to let go a more commercially-oriented, problem-solving style of research? If that is what the nation wants universities to do, then I think this is a real area where perhaps we need some new specialized institutions separate from universities to do that.

And that the struggle to hold onto that may be more damaging to the universities' other missions than is worth just keeping them afloat.

HUANG: Alice Huang, NYU Several speakers have spoken about the size of the Ph.D. cohort that we ought to train. And I think this deserves some attention. And I would like to know what the panel thinks about limiting the numbers of Ph.D.s

I for one would hate to see that limit come about because I feel that in an open society such as ours, by limiting the numbers of Ph.D.s, we will be limiting the opportunities for those individuals who can aspire to those positions. And also by limiting any profession we fall into a state of protectionism, thereby limiting the competition in that profession.

KEISER: Bonnie Keiser, Rockefeller University. I direct a program for pre-college students and teachers. They come into the graduate research laboratories and perform research. High school students are well capable of cloning genes. They really understand what they're doing.

My question is more of a comment. When we talk about graduate research and teaching I think we all have a shared mental model, an apprenticeship model that is the delight of the world. But when we talk about education, I think many of us are unaware that there are wonderful things happening in education that are coming closer to an apprenticeship model.

And I think we shouldn't be so scared when we talk about research or teaching because there is evidence that teaching in some cases is moving closer to a graduate model. Rensselaer, undergraduate physics, cost-effective total laboratories, City College workshop chemistry, cost-effective higher retention rates. Smaller group sizes, discussion.

SCHWARTZ: I'm David Schwartz, former president of Schwartz Bioresearch and a vice president of Becton Dickinson. I have this question that has nothing to do with what has been said so far, but I think is extremely important.

I recently gave a talk at the New York Academy of Science entitled "Science: From Hero to Villain in One Generation." We need friends. And the place where friends and understanding of science is optimally obtained is in the research university. All the pieces of the future body politic are there in a formative stage.

And I think it's up to the research university to see to it that scientists mix with nonscientists, that the future lawyers and the future economists understand each other. We're not doing that. There's a lot of isolation. It's bad for science. It's bad for the body politic. And I don't know of any other place. And here are two ex-university presidents and a provost, and I can't think of speaking to this issue to any better people. Thank you.

MALE VOICE: We've had an extraordinarily rich presentation, which gives rise to a lot of thought. I just want to bring one thing up. You talk about the number of graduate students and the small number of jobs in science. And my own professor produced 80 Ph.D. s in his active life. But that pathology of the imbalance has existed for a long time in the humanities departments. And the humanities departments have dealt with it, say, in French by letting in lots

of graduate students so they can get a lot of teachers, and then having lots of barriers to the Ph.D. so they produce very few Ph.D.s. And they take an awful long time. So that the costs per Ph.D. production in French is greater than the cost of Ph.D. production of a chemist because of the small ratio between the entrance and the exit. The only jobs they're looking for are professors, And I guess the question I would ask is, do you see chemistry departments becoming like French departments in the future?

MALE VOICE: We can kind divide up these very quickly. Let me handle just a couple of comments on the Ph.D. and also the merging of scientists and humanist and social sciences on our campuses. I'll be somewhat more radical and suggest that rather than having birth control or limiting the number of Ph.D.s, I think the Ph.D. needs to be dramatically restructured.

In the COSEPUP (Committee on Science and Public Policy) Report from the National Academies a couple of years ago, there was a preliminary draft that proposed consideration of a two-plus-two-plus-two-to-infinity model. What we call the Ph.D. would be a four-year fixed-term degree: a master's degree of two years, a four-year Ph.D. Probably not a degree appropriate to put people into the academy, at least into the research university.

Last year, of the 3,000 graduates of my liberal arts college at the University of Michigan, over a thousand went on to law school. Thank God, not because they want to practice law, but because they feel they need an advanced degree that gives them breadth and further opportunity.

A Ph.D. could do this quite well. Although it's based upon specialization, it gives individuals the capacity for intellectual adaptation. And if we made that a fixed-time degree, it would handle many of these issues and broaden it out.

Second, I agree completely that we need to recreate the dialogue between science and humanists and others on our campuses. But let me suggest the place to recreate that dialogue is in undergraduate education. The same kind of specialization that we prize so highly right now in our scholarship has led to a compartmentalization in how we approach undergraduate education. It does deep disservice to our undergraduates and breaks faculty apart. If once again we were to create a totality, a certain coherence in undergraduate education involving scientists, humanists, artists, and social scientists side by side, maybe that's the place we'd create the dialogue. Don't

KENNEDY: On Alice's thoughtful observation, enlarge the expectations. And change the style of training rather than limit the numbers. I want to thank Bonnie Keiser for bringing up the interesting subject of inquiry-based instruction and its capacity for remarrying some of the notions we have about research and education even at K-12. It's a terribly important revolution. And it's one that relates, I think, to Dr. Schwartz' thoughtful plea about needing understanding friends. I think there is a way to teach science that engages people much more deeply and systematically with the way science is done, and that's the kind of understanding that we need out there.

MACAGNO: I think that for us to proliferate Ph.D.s poses a lot of problems, because I don't know how we are going to support them. At least at this point in the sciences, we have a certain amount of funding that comes from federal sources, training grants, and so on meant to support

the research phase. And with a small additional amount, we can actually support the students fully. But if we were to go into that mode that you're talking about, either we would have to develop other funding methods or the students would have to pay – which is, by the way, what they often do in the humanities and social sciences – and get a tremendous debt that they can't deal with later.

DAVID: I wanted to come back to the sense of loss of community within the university, as driven by specialization and by the external orientation of research faculties. I think this is clearly an important issue. I think it's essential, if it's going to be addressed, that one recognize that although the creation of the single investigative grant and the development of the mobile professor as part of the American university scene could be something laid at the door of the research foundations, it is also the case that university administrations responded to the incentives created by the research system in allowing a reputation-based system to drive the entire process. That a set of incentives was created for faculty to invest in what they did for their invisible college, for the people who reviewed their grants, for the people to whom committees wrote for appraisals for outside review.

I don't think that it's possible in the logic of a collegiate reputational system to substantially do away with that. A question that does exist is whether it is possible for universities to try to internalize by forming either stable, collaborative groups with other universities to have faculty members have the feeling that there is a connection between their reference group and their research groups and the set of institutions whose joint interest can be promoted. If we have shared facilities, if you have more remote access, if you have more interuniversity cooperation, groups of universities can internalize some of this. We have seen this happening in the Research triangle. It can happen in other places. But it requires both an external change and a change in attitudes on the parts of university administrators.

COLE: Thank you. I have been terribly restrained in my own remarks. I would love to say a good deal about some of the observations made by my colleagues and others here.

I was particularly interested in the extent to which there exists public illiteracy about science and technology, and tried to begin to understand – and I underline begin to understand – why that is so. And I began to conduct a very unsystematic study with the help of a colleague of mine, Dr. Eleanor Barber, who is here. I asked leading American historians of the postwar period to tell me what they thought were the best books that had been produced on the subject, the leading textbooks used in colleges and in secondary schools, with the aim of seeing what young extraordinarily intelligent students who are not going into science are learning about the process of discovery and the actual discoveries of American science since Bush's report appeared in 1945.

And we did that study. I was going to report on some of the results. But, as you can imagine, to say there was a paucity of references to not only the achievements of science and technology but to any aspect of it whatsoever in the works of our leading American historians wouldn't be a matter of hyperbole – it would be understatement.

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I can tell you there are more references to Madonna than there are to DNA or to Watson. And Crick does not appear in any of these books. The Atomic Energy Commission, the nuclear explosions are referred to on occasion. Occasionally, there's a reference to computers and computer technology. But it is almost totally absent from the books that are read by people who will go on and become members of Congress and who will be the people we'll be asking for support for science leaders in the society outside of the scientific establishment. And they do not get very much of this, as you review the curriculums of not only undergraduate American history but graduate programs in American history.

Part of it is that the people who are teaching these courses, extraordinarily able people, are totally untrained and ignorant themselves of the achievements of science and technology. That is something educationally we can begin to deal with at universities like Columbia and others, and one that I think requires more attention.

I note that the Sloan Foundation has given a very substantial grant to MIT to bring together some quite extraordinary American historians to try to create a history of science in the postwar period – to integrate the story of the growth, the extraordinary expansion of science and technology during this period into the institutional, the political, and the cultural histories of this nation since 1946.

We'll reconvene here in the proverbial ten minutes. Thank you. (applause)

COLE: I'm going to turn the podium over to my friend and colleague Richard Nelson, who will do the introductions for this next session. Why don't we take our seats if we can. Thank you.