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FROM: ADAMANY, David: WAYNE STATE UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/17/92

SUBJECT: HE IS FORWARDING THEIR COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND THE NATION'S RESEARCH INTENSIVE
UNIVERSITIES.

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August 17, 1992

32 AUG 26 AM 11:55

Mr. D. Allan Bromley
Assistant to the President
Science and Technology
The White House
Washington, DC 20500

OSTP
MAIL ROOM

Dear Mr. Bromley:

Thank you very much for your letter of June 8 reporting on the review being conducted by the President's Council of Advisors on Science and Technology of the partnership between the nation's research-intensive universities and the federal government.

It is my hope to attend the meeting scheduled on September 24 at Northwestern University in Evanston, Illinois. I will call to make appropriate arrangements as soon as my schedule is firmer.

In response to your invitation to comment on this issue, Garrett Heberlein, our vice president for research, convened a group consisting of deans, department chairs, and faculty from science areas across our campus. The enclosed statement reflects their comments on the relationship of the research-intensive universities to the federal government and the most pressing issues facing that relationship for the future. While I regret that our statement is so lengthy, it reflects the extensive concerns of science leaders on our campus and the breadth of our relationship with the federal government.

I hope this statement is helpful to you and the President's Council of Advisors on Science and Technology. And I also hope to participate in the PCAST meeting scheduled on September 24.

Thank you once again for inviting the participation of Wayne State University.

Sincerely,

David Adamany
President

plw
j:dbromley.ltr

Enclosure

THE FEDERAL GOVERNMENT-RESEARCH UNIVERSITY RELATIONSHIP

A Statement Submitted by Wayne State University
to the President's Council of Advisors
on Science and Technology

The tremendous research capability of this country and the technological advances that it has provided allow us to enjoy a standard of living that is unsurpassed in the history of mankind. Compare, if you will, our present knowledge and technologies in agriculture, aviation, communication, engineering, medicine, surface transportation and weather forecasting, for example, with the state-of-the-art in these fields one generation ago. Some diseases which were the scourge of that generation have been all but been eradicated. Tragically, new and even more frightening ones have appeared. The entire technology of miniaturized electronics, from computers to portable audio and video equipment, were but a dream 25 years ago.

While it is clear that our society is benefiting from advances like those noted above, the critical role of the research university in making them possible is not always understood. What is apparent is that these individual examples are the collective products of an earlier wisdom, namely, that as a nation we must continuously invest in our future. We are now at risk of disinvesting in our future.

There are several reasons why we have lost sight of the need to continue investments in research. Many steps and lengthy time delays often occur between critical research findings and the

production of new products or processes. Also, many products and processes are the result of numerous research investigations conducted over many years, by many people, in separate locations, which when taken individually generate little notoriety or public interest. Furthermore, many studies that are done for important scientific reasons have no obvious or immediate social benefit to persons unfamiliar with the process of discovery.

Contemporary higher education is inextricably linked to research, for unless the frontiers of knowledge are continually explored, our workers and leaders of tomorrow will lack the forward momentum and competitive edge that are needed to sustain the country's current standard of living.

While our research universities and our graduate programs are among the greatest of our national treasures and are currently the envy of the world, they are underutilized and at risk. The federal government and our national research universities must strive to work together more effectively to insure that the full potential of the research universities is achieved and that the existing strengths are not jeopardized through benign neglect or inadequate support. We believe that this country possesses no single greater resource than its youth. Insofar as science and math are concerned, a revitalized investment should be formulated, one which emphasizes an infusion of training from the bottom up. For too long, the national investment has begun only after a student has completed his or her initial 12 years of education. Such a commitment requires an examination of our entire science education

infrastructure. While there are many issues of mutual concern to the federal government and the research universities, we strongly urge that some immediate attention be given to the items below.

SCIENCE EDUCATION

Many research universities, in partnership with the nation's school districts, are uniquely positioned to spearhead efforts to increase the pool of young people in the United States who are well-trained in science, mathematics and engineering. These universities, however, lack the resources to implement the necessary programs. Federal funding can strengthen ongoing collaborations and develop new local and regional consortia to improve the technological literacy of society and specifically increase the number of students studying science, mathematics and engineering.

Teacher preparation and continuing education: Most elementary and middle school teachers have little or no background in basic science. University scientists and educators can offer workshops to teach everyday science, emphasizing regional biology or ecology, chemistry applied to everyday experiences, as well as the basic principles of physics and mathematics. They can develop simple, prepackaged experiments and course materials for classroom use. High school educators, who have basic training in their subject areas can be introduced to in-service courses set in research laboratories. These programs require support for faculty members in the summer to teach and conduct workshops and support for the

teachers who will be asked to spend a portion of their summer or time after school or weekends to participate in such programs. Programs of this type - workshops, summer institutes and research programs - have been successful in the past but have been funded only on an occasional basis by the federal government. These programs need to be given stable, long-term support. The most effective way to organize these programs is on a local or regional basis where it is possible for long-term relationships to be developed between local school districts and universities as well as between teachers in the elementary and secondary schools and university faculty members. These interactions should be ongoing and provide continuing education and support for programs at all levels throughout the academic year.

Student programs: At the primary and secondary levels, the University faculties can work with teachers to provide age-appropriate opportunities for demonstrations, field trips, special events and programs to heighten interest.

At the college level, special efforts should be made to introduce students to research. This can be done by providing summer and academic year research programs at colleges and universities and especially by pairing colleges with nearby research universities. Students who are involved in undergraduate research tend to continue in graduate or professional schools and to pursue research careers. To be effective, these programs need to be at students' home institutions or at institutions within reasonable driving distance where both summer and academic year

research can be carried out. For this reason, emphasis should be placed on locating these programs in urban regions where the students from non-research programs can participate in research programs, seminars and related activities throughout the year.

Curriculum review, development and testing: Science and mathematics faculty can provide an overview of key concepts and themes. They are familiar with new developments, with rapidly advancing areas and with specialties which are likely to emerge in the future. University faculty and teachers should work together to review textbooks for accuracy, emphasis and effectiveness. Teaching methods, laboratory exercises, field trips and audio visual material should be assessed as well. Two-way communication and an emphasis on the joy of discovery are the keys to success.

Facilities and infrastructure: Research universities have in place resources -- libraries, computer-aided instruction laboratories, video production facilities and the like -- which can be valuable as school districts redesign what and how they teach. These resources, beyond the scope of a single school or district to purchase and maintain, can be maintained at the university and shared with the schools. Funding mechanisms, however, need to be developed.

Assessment and tracking: Universities have the means of assessing the impact of programs on education. Similarly, universities can maintain databases that cross school district lines. These are important for networking teachers, tracking students with science and math aptitude and recruiting students for

special programs.

Role of the Federal Government: Present support mechanisms through NSF, NIH and private foundations are sporadic. Programs must be continually reinvented. Personnel must be repeatedly recruited and trained. Commitments cannot be made to long-range projects since funding is problematic from year to year. Costly equipment is frequently at risk for lack of on-going maintenance support. The development of long-term relationships between school districts and their teachers, on the one hand, and universities and faculty members, on the other, is impeded by this on-again, off-again support. Government must make long-term grants to those research universities that recognize the need and will support regional centers for science and mathematics education. Similarly, government must make awards to those school districts and individual educators eager to participate in the centers. Funding support at the local/regional level will strengthen ties between the local school districts and the universities, and it will increase the chance of success for long-term interaction between the primary and secondary schools and the universities. Establishing common goals and maintaining appropriate relationships requires realistically-sized regions where all of the participants - students, teachers and university faculty members - can regularly meet and work together. This is the only way in which long-term, cost-effective support mechanisms can be developed.

GRADUATE STUDENT SUPPORT

Increased graduate student support is a strategic goal that is of critical significance to the economic well-being of the country and the integrity of our graduate programs in areas of national need. Graduate students are the lifeblood of the laboratory process of discovery. It is at this educational stage where diverse concepts are co-mingled, and the best ideas emerge as the next wave of discovery. Graduate students, with their idealism, vigor, and oft-irreverent regard for the dogmatic approach of the more established scientist, will inherit from their mentors the ideas and knowledge necessary to sustain our national preeminence.

It has been repeatedly reported by the National Science Foundation that a large and growing percentage of doctoral students in science and engineering are from abroad; and in some fields, a majority of doctoral students are foreign nationals. The reduction in graduate student support by the federal government during the past two decades has worsened the decline in graduate student enrollment in math and science. A substantial increase in federal fellowships for graduate study in crucial disciplines is needed.

It is possible to combine the commitment to science education in K-12 schools with the strengthening of doctoral programs by increasing the number of doctoral fellowships. In many urban areas, it is now virtually impossible to recruit math and science teachers. The teaching of math and science often falls on the shoulders of K-12 faculty who were certified in these fields many years ago, or whose certification in math and science is a secondary or minor certification. Such faculty often are required

to teach math and science because of an absence of others who are qualified, or because of "bumping" during school layoffs.

Considerable support for math and science teaching could be provided if doctoral fellowships in math and science were provided to urban universities with the understanding that for two of a doctoral student's four or five years of study, he or she would teach 15 hours per week in an urban school. This would allow courses and laboratories in basic sciences, such as physics and chemistry and biology, to be offered to high school students by teachers who are current in the subject matter and deeply involved in it.

RESEARCH FUNDING FOR JUNIOR FACULTY

It is critical to the health and well-being of a nation's basic research enterprise that the research universities be able to employ and nurture a continuous supply of young, talented faculty members working in the sciences. These are the people most apt to initiate contemporary research programs utilizing advanced technology at the cutting-edge of the discipline. As a result, these young faculty play an important role in directing research programs of great potential benefit to the country and in passing on the most current knowledge to a new generation of students.

The costs associated with getting a new faculty member started in the experimental sciences is high. The cost to the university to equip a new faculty member in these research areas is almost never less than \$150,000 and often can be as much as one million

dollars. It is legitimate to ask whether an investment of that magnitude can be justified in untested faculty research. However, if a university is to invest in an important research area by building faculty expertise, it is essential that the required research tools be available. Purchasing the scientific instruments required to conduct sophisticated research is a prerequisite to hiring a young faculty researcher in an experimental field. Decisions about whether to purchase expensive instrumentation and how much to purchase are critical to the ultimate success of young researchers. The aggregate cost of laboratory set-up for new faculty to a large university, especially one attempting to build its research programs, can be staggering.

A large initial investment in laboratory set-up, even for very talented young faculty, does not insure a successful research program. There are other factors that are also important. One is that research in the experimental sciences is usually best carried out by teams made up of the faculty director/mentor, doctoral students, post-doctoral students, and, perhaps, technicians, undergraduate students, etc. This is a very efficient organization for basic research and for graduate education in the sciences. On a relative basis, it is also quite cost effective since the student talent is often excellent, the motivation is high, and student stipends are not large. However, costs are by no means trivial, and the funds to support the team and purchase research supplies must, in general, come from federal funding agencies by way of peer-reviewed grant proposals. In periods of severely limited

research funds, it is very difficult to secure the funding necessary to operate a research team with sufficient critical mass to make progress on important research problems. The task is even more difficult for a relatively inexperienced person who has yet to establish a substantial reputation as an independent researcher. Most often, young faculty members find themselves in a head-to-head competition with established researchers for the funds required to support a viable research group. It has become increasingly difficult in recent years, as a result, for young faculty members to initiate a competitive research program.

Thus, even after the university has committed considerable resources to insure that a young faculty member is able to begin a productive research and teaching program, success is problematic unless he or she is able to secure federal research funding. Both set-up funds from the university and grant funds from federal agencies are necessary components in the initiation of a successful research program. There must be a close working relationship between the research universities and the federal government to make sure that young faculty members are given the opportunity to succeed since these people are vital to the nation's future basic research enterprise.

The "set aside" programs for junior faculty in several federal agencies have been working well and should be continued and enhanced. A program that has been a great benefit to universities in the past in providing funds for new faculty in the biomedical sciences is the Biomedical Research Support Grant (BRSG) program in

the National Institutes of Health. Unfortunately, this program is now in jeopardy due to lack of funds. Not only should this program be continued, but it should be replicated in the NSF and in other agencies that depend heavily upon university research for their success.

MAINTAINING DIVERSITY AMONG THE RESEARCH UNIVERSITIES

Research universities in the United States have many things in common; however, they are also diverse in the populations they serve and the areas in which they excel. Some research universities have primary strength in agriculture while others have major strength in medicine, or business, or areas within the physical or social sciences, or engineering. Some serve predominantly 18-30 year olds while others serve a much broader spectrum of ages. Some are located in rural settings and cater predominantly to mobile students who can establish residence at the campus, while others reside in urban environments and serve the needs of less mobile and often culturally diverse students.

The federal government must strive to maintain the current diversity and strength of the nation's research universities to insure that we develop the full potential of our population and maintain a strong competitive position in the international marketplace. A few research universities in a nation of our size cannot achieve research excellence in all areas and develop the scientific manpower that is necessary in all regions and economic sectors, given the diversity of our population and the knowledge

base in the world today. A reduction in the number of adequately supported research universities will certainly damage the nation's standing as the world leader in graduate education, since research and graduate education go hand in hand.

We must insure that our allocation of federal research funds are merit-based and are also sensitive to the nation's size, population dispersion, economic complexity, and diversity. Only in this manner will we have a truly competitive system which encourages growing institutions to become better and established institutions to enhance their current levels of research excellence. Academic institutions with special expertise throughout the country must be able to secure reasonable research funding in areas where there is strong national need and when a unique research opportunity arises.

There was substantial growth in federal funds for academic research throughout most of the 1980's. This proved to be of great benefit to both the economy and health of the entire country. Most of these research funds were distributed through peer review processes. Careful analysis, however, suggests that the peer review system as currently practiced by the federal agencies may be discouraging the kind of diversity that is critical to the country's research strength over the long term. Look, for example, at what has been happening to the universities ranked in the top 100 by the National Science Foundation based on research expenditures (see Figure 1.) If one compares the growth of these institutions throughout the 1980's, one finds that the institutions

with the highest rankings increased their expenditures (and by inference their research revenues) at a rate considerably greater than the increases in research expenditures recorded for institutions with a lower ranking. In other words, in the 1980's, the bigger research universities, on average, got bigger faster or received a larger percentage increase in research funding than did the smaller research institutions. If this trend continues, one can predict that there will be substantially fewer and a less diverse group of research universities in the U.S.A.

RESEARCH FACILITIES AND INSTRUMENTATION

The 1986 Packard-Bromley report, "A Renewed Partnership," estimated that America's colleges and universities needed about \$10 billion over a ten-year period for science buildings and research laboratories. It called for 50% cost-sharing by the federal government for these facilities. This investment has not occurred. The entire NSF program solicitation for repair, renovation, and equipment was \$33 million in FY92. This is such a small fraction of what is needed that the NSF has requested \$33 million for academic research instrumentation and zero dollars for research facilities modernization for FY93. Even this level of funding is not adequate to address the extraordinary cost of research instrumentation which would fall under the NSF mandate. Consequently, the hard choice has been made to defer funding for facilities modernization altogether. Hopefully, this is but a short-term decision.

Overall federal funding for research facilities appears, at first sight, to be in somewhat better shape for FY91-93 until one realizes that most of the facilities investment is in the form of the SSC and various other large-scale national facilities.

Universities have been faulted recently for coaxing and cajoling members of Congress to make end runs around traditional merit review procedures in order to "earmark" R&D funds, almost always without floor debate, for new facilities or programs at particular institutions. The 1992 budget passed by Congress is reported to have contained 143 R&D "earmarked" items amounting to \$346 million to colleges and universities. This is clearly not a desirable method for making funding decisions so critical to the long-term health of the nation's R&D infrastructure. While individual institutions and their congressional sponsors must each make individual assessments of their needs and desires for such support, the "ear-marking" system is without scientific peer review and thus denies the very type of critical assessment that lies at the heart of our merit-based process. On the other hand, a sustained inability or unwillingness to invest to a level approaching the Packard-Bromley recommendation will encourage such "ear-marking."

Means should be found to begin to implement the original recommendation of the 1986 Packard-Bromley report. A \$10 billion effort over a ten-year period for science buildings and research laboratories is even more urgent today than it was when first put forward. As was suggested in the original recommendation, cost-

sharing should be sought from among the federal government, the states and private industrial sources.

INDIRECT COST ISSUES

Indirect costs associated with extramurally funded research at universities have become controversial. They are the subject of intense discussion within universities and between federal agencies and universities. This issue, unfortunately, has also been drawn into the national political agenda.

A variety of concerns bear on this issue. Indirect cost policies create tension both within and outside universities. Within the university, the charging of indirect costs often aligns faculty against administrators because of the desire of faculty to minimize research proposal budgets in order to optimize competitiveness. The development or change of federal indirect cost rates for a university is a complex process involving protracted negotiations with federal agencies. Sponsorship of research programs at universities has become more complex, including combinations of federal, state, local and private support mixed with entrepreneurial activities by faculty. Universities are facing increased research infrastructure costs deriving from new and increasingly intricate regulatory requirements, aging research facilities and equipment, underfunding for the increasing direct costs for research, fluctuation in research funding patterns and priorities, and increased costs of university operations in general. Universities are seeking indirect costs to cover the real

research infrastructure costs, whereas the federal government is seeking to reduce costs in order to provide additional direct cost support for programs. There is also a vigorous effort by the federal government to scrutinize, if not to redefine, the basis, at universities, for indirect costs.

We strongly support the basic principles upon which federal sponsorship of research has developed as direct and indirect cost support for university-based basic research:

- a. Universities provide the best environment for the conduct of basic research.
- b. The federal government should support the full cost of research, without requirements for matching or cost sharing by the institutions.
- c. Research (and training) is funded through a wide variety of competitive, peer-reviewed, merit-based grants and contracts.
- d. Research and the training of scientists are tightly linked enterprises within the universities.

The basic principles of indirect cost awards to universities for support of research and contract awards are valid, valuable, and reasonable. Our perspective is that the issues of concern about indirect costs are primarily those of processes or interpretation of the factors or values comprising university indirect costs in support of research.

Some of the specific problem areas with indirect costs are:

- a. Increasing administrative costs to universities

associated increasing federal regulations, on the one hand, and a desire on the part of the federal government to cap the reimbursement rate for administrative cost for research, on the other.

- b. Lack of consideration in the indirect cost formula for reimbursement of technology transfer costs associated with economically important discoveries arising out of federally supported research.

We recommend modifications in the indirect cost mechanisms to address current problems as opposed to changing the support mechanism, e.g. block grants. We favor the establishment of a uniform federal indirect costs process that includes both a uniform rate base and the linkage to direct costs awards.

CONCLUSIONS

This country has enriched subsequent generations with the products of its research investments. We believe the commitment should be reexamined and strengthened by supporting K-12 science education, doctoral study in science and engineering, young scientists in the early stages of research careers, and research infrastructure. Such commitment will require a national declaration of urgency and must involve the full participation of the research universities. Following appropriate national discussion, the federal government should identify a minimum percentage of the gross national product that should be dedicated to these endeavors. State and local governments would be

encouraged to do likewise. A stable, long-term commitment of resources will assure that future generations will possess the necessary information and knowledge to improve their lives and prepare society and the world for the generations beyond.

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FROM: BYER, Robert L.: STANFORD UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/12/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

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Robert L. Byer
Dean of Research
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August 12, 1992

Dr. D. Allan Bromley
Director Office of Science & Technology Policy
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OSTP
MAIL ROOM

Dear Dr. Bromley,

On Wednesday July 15, 1992 I was invited to testify before the President's Council of Advisors on Science and Technology regarding issues of federal relationships with research universities.

I chose to speak on one key issue regarding that relationship; OMB Circular A-21 the document that sets the costing principles for sponsored research between the federal government and the research universities in this country.

A summary of my oral presentation is enclosed. Also enclosed is a document which has been more than six months in development at Stanford University which sets out a proposal for modifying OMB circular A-21. As you know, we are intimately familiar with the application of the costing principles which have been at the heart of the controversy regarding indirect costs in support of our investment in higher education and research at our research universities. I believe that our proposals for modifying A-21 are sound and that they will lead to simplification and to a fairer application of what is, at its heart, an elegant document.

Sincerely,



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Robert L. Byer
Dean of Research
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July 15, 1992

Presentation to the PCAST Committee

Robert L. Byer
Dean of Research
Stanford University

A Proposal for Modifying OMB Circular A-21

Introduction

The fifty years of partnership between the federal government and the research universities established following world war II is now being tested and renegotiated. It is essential that we recognized the underlying principles that we wish to preserve before suggesting changes to an arrangement that has produced scientific research and research universities that are the envy of the world.

I will limit my remarks this morning to the cost reimbursement principles embodied in OMB Circular A -21. As our incoming president, Gerhard Casper stated at his first news conference held at Stanford earlier this year, A -21 is an elegant document that recognizes the historical relationship of the government to public and private universities. It allows full reimbursement of research costs across a wide variety of universities from public to private to secular while preserving appropriate separation of the government from the direct support of these institutions. The underlying principles of A-21 are sound and should be preserved. Let me review those principles.

Underlying principles

The core issues embodied in A-21 that should be preserved include:

The Reimbursement policy must be based on documented incurred costs rather than arbitrary rates or allowances.

Cost sharing between the government and the Universities exists and has risen dramatically in recent years. Cost sharing should be recognized in the implementation of the A-21 costing principles.

The treatment of sponsored research as an investment must be reemphasized. In recent years research has often been treated as a procurement by the agencies and by the accountants.

The indirect cost reimbursement must be simplified so that policy makers and the public can understand the reimbursement process and make appropriate decisions regarding research support

Once established, the revised principles should be applied in an equitable manner by the cognizant agencies so that "fair and equitable" reimbursement is achieved in practice.

Stability in the reimbursement process needs to be achieved. It takes on average five years of investment to train a PhD student. This unit of a 'graduate student lifetime' should set the time scale for indirect cost rate stability.

PROPOSALS FOR MODIFYING A-21

The indirect cost rate needs to be redefined in a manner that is understood by the public and by public policy makers.

The current statement of indirect costs as a fraction of the MTDC (modified total direct cost) base is not easy to describe. Excluded from this base is capital equipment and subcontracts in excess of \$25000. Unfortunately, most people interpret the Indirect Cost Rate as an "administrative fee" applied to the research direct costs and not as component of the costs. After some explanation, it is often possible to explain the esoteric accountant definitions that describe the rate. However, it is much easier to calculate the rate as a fraction of the total costs of the research program. At Stanford the ICR has risen from 55% to 74% over the decade of the 1980s. However, this rising rate was applied on a declining MDTC base. The actual dollars reimbursed to Stanford as indirect costs, as a fraction of TOTAL dollars spent on research, was a constant 33% over the decade.

This is not an insignificant issue when it comes to explaining the supposed "high" costs of research. For comparison, the ICR for companies is proprietary, is displayed in multiple sub-rates in the research budgets, and is at the 150% to 200% level if applied on the MDTC used by Universities.

The Indirect Cost Rate should be negotiated for a period of 5 years and be based on a detailed, audited, cost proposal using a base year.

Stability in the cost reimbursement system is essential for the health of the research enterprise. Negotiating an indirect cost rate for a five year period would reduce substantially the current cost of auditing, proposal preparation, and submission. At the end of the five year period, say 18 months prior, a new indirect cost proposal would be prepared, audited, and submitted for the next five year period. This procedure would reduce the risk to the institution of an arbitrary, capricious and unilateral action by the federal government or by the university regarding sponsored research.

Reduce the Indirect Cost Pools to three: Administrative Costs, Operating Costs, and Capital and Equipment Costs.

One of the difficulties of explaining the pooled cost accounting approach, is the description of the current seven cost pools of which two are small and dissimilar to the larger more familiar cost pools. This proposal would simplify the cost accounting. Further, by establishing "threshold rates" for similar institutions and similar cost pools, institutions would have an incentive to reduced indirect costs to a level below the threshold rate to avoid the auditing costs. This incentive mechanism would help to contain costs. However, the threshold rates would have to be realistic and be determined for similar institutions.

In setting indirect cost rates, it is essential to avoid the use of arbitrary caps on rates. The unavoidable consequences of caps is an unequal cost reimbursement across different institutions and an incentive to move direct costs to the capped indirect cost pools by the funding agencies.

Robert L. Byer
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Capital and Equipment costs deserve special mention because they are at the heart of much of the long range investment in research. First, to keep new buildings from impacting the indirect cost rate, a two or three year direct cost support should be put into place to allow the transition the new building to full operation in support of research. Second, Shortened, more realistic building lives should be recognized as suggested by the 1986 White House Science Council.

Capital equipment should be redefined as any item costing \$5000 dollars and having a one year useful life. At Stanford this would capture 80% of the capital equipment value but reduce the cost of administration significantly relating to the inventory of capital equipment items.

Institute an appeals process and retain multiple cognizant agencies.

The government is a monopsonist when it comes to research support; that is the federal government supports that vast majority of research and can control the cost of research unilaterally. There is a need for balance in the negotiation process; an appeals mechanism would provide that balance. An independent, speedy, appeals mechanism must be incorporated into the A-21 costing principles to prevent the cognizant agencies from holding Universities "hostage" during the negotiation of an indirect cost rate.

Agencies in addition to HHS and ONR need to act as the cognizant agencies for the application of A-21. Competition is healthy in the government as well as in the private sector. Lets provide incentives for agencies to become cognizant agencies and open the door to wider participation.

A statute of limitations needs to be established for closing past years

At present there is no limitation on the number of years that may be kept open for audit purposes. This gives enormous leverage to the cognizant agency and the auditing agency in the negotiation process. There needs to be a recognition that timely audits, negotiation, and resolution is essential to health of sponsored research. Lets prevent the repeat of the Stanford experience where ten years remained open due to the lack of timely audits. The result was a factor of ten leverage upon audit and costly time consuming audits over many past years. If the agency and the government do not audit in a timely manner then provide for an appropriate resolution of the incurred costs report and for a closing of the fiscal year.

Conclusion

I cannot conclude however, without mentioning the issues that is of utmost concern to the faculty at Stanford: **TUITION REMISSION**. Stanford, along with Caltech, Columbia and MIT are the only Universities that still remit tuition to RAs and TAs through the staff benefit rate. This method of remitting tuition has been shown to save the government money by spreading the costs over a wider base of university employees. It has the added advantages of providing stability to graduate student support; insulating the students from the wild swings in research support of a single faculty member. Tuition remission a larger number of graduate students to be trained especially in science and engineering.

Keep it simple, straightforward and elegant

Robert L. Byer
Dean of Research
Professor Applied Physics
Stanford University
Stanford, California 94305

The only MOU, or advanced agreement, not unilaterally canceled by the ONR representative in April, 1991 was tuition remission. I am convinced that our faculty argued persuasively to keep the MOU governing tuition remission. Their estimate of the impact on research at Stanford of the cancellation of that MOU would be a reduction in the number of graduate students by between 25 and 33%. Thus tuition remission is not an accounting issue but an issue of national policy. This committee should urge OMB to study the impact of tuition remission carefully before moving to make recommendations in this area.

These are suggestions that should be considered to improving the A-21 cost accounting principles that govern the cost accounting for sponsored research. The goal is to strengthen a partnership that has proven enormously successful over the past fifty years.

Office of the Dean
Cypress Hall
(415) 723-0977
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Ginzton Laboratory
Room 283
(415) 723-0226
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A Proposal for Modifying OMB Circular A-21

Federal Indirect Cost Reimbursement Related to University Research

Prepared by Stanford University

August 1992

Introduction

During the 50 years that the federal government has sponsored basic science research, a partnership has evolved between the government and universities that has greatly benefited the United States. Under this cost-sharing partnership, universities provide facilities and faculty salary support, and the government covers the direct costs of technicians, graduate students, and supplies, as well as most of the indirect infrastructure costs related to institutional support of research.

Universities now conduct more than two thirds of the total basic science research in the United States. The United States leads the world in basic and applied research in engineering, the sciences, medicine and other areas of discovery and training — a result that attests to the success of the government-university partnership. The partnership is also a major reason for the enormously successful graduate education programs in science and engineering that American universities have developed over the last half-century.

During the past two years, the partnership has been shaken. The principles that govern the payment of indirect costs of federally-sponsored research have been challenged following some troublesome events with which Stanford is painfully and intimately familiar. As a result of that controversy, the system of reimbursing indirect costs, as set forth in Office of Management and Budget Circular A-21, is under review.

With the goal of helping to create a more equitable and understandable indirect cost system, we hereby propose four major changes in the process of reimbursing universities for their costs of research. First, however, we put forth a series of principles upon which these proposals are based and that should be considered when discussing changes to A-21.

The underlying principles of indirect costs

The research partnership has prospered under A-21, benefiting the public as well as the government and universities. Some aspects of A-21 can be modified to achieve greater equity and efficiency, but its core principles, which have been developed over many years, are sound and ought to be preserved. In considering changes to A-21, the following central issues should be considered:

- The partnership, and the mechanisms that make it work, should promote the fundamental interests of the nation as a whole. They should foster a vibrant and creative research enterprise that advances basic knowledge and develops applied uses for that knowledge. They should further the enduring growth of that research enterprise.
- Reimbursement policy should be based on documented incurred costs rather than arbitrary rates or allowances.
- Cost sharing is an essential part of the research partnership between the government and universities. The universities' portion of research costs has risen significantly in the past few years; increasing that burden would have a detrimental effect on the ability of universities to continue their leadership in basic research.
- Teaching and research at universities are inextricably intertwined. Therefore, the application of A-21 should reflect the unique characteristics of educational institutions, which differ significantly from other entities which contract with the government.
- As the White House Science Council states, federal agencies should recognize that the government's sponsorship of university-based research is quite different from a "procurement" relationship. "We must return to the viewpoint that federal support of such research is a long-term investment in the Nation's future rather than the procurement of a necessary product," the council's 1986 report states. If the government regards research as a good to be procured, then it would merely try to seek out the lowest bidder. Historically, we have prudently followed a different approach, one that is widely credited with producing the most creative and productive research enterprise in the world. We have placed great emphasis on quality, and have selected research projects on the basis of merit.
- Indirect cost reimbursement has become increasingly complex over the years. The recent controversy over indirect cost has demonstrated that both universities and the government would benefit from its simplification.
- The principles of A-21 should not be subject to widely varying interpretations. Once rules are published, government agencies should apply them consistently. Moreover, application of the principles of A-21 should result in "fair and equitable" reimbursement of an institution's indirect cost when viewed by an objective third party.
- The level of reimbursement should not be subject to significant year-to-year variation.

With these principles in mind, we are proposing four basic changes in indirect cost reimbursement that will simplify the process and make it more equitable than the current system.

Proposals for Modifying A-21

1. Redefining indirect cost rates

The current practice of expressing indirect costs as a percentage of modified total direct costs (MTDC) has the effect of *exaggerating* the apparent trends in indirect costs. The National Institutes of Health have reported that indirect costs have changed minimally as a proportion of total costs since 1984. Similarly, indirect costs at Stanford have remained stable at about 33 percent of total costs for the past ten years. Yet indirect cost *rates* have risen because the use of MTDC overstates true growth, since spending on equipment and subcontracts (which are excluded from MTDC) has increased. It is essential that we employ terminology that is accurate, descriptive, and informative. *We propose that indirect cost be expressed as a proportion of total research costs, although the method of determining indirect cost rates need not change.* Expressing indirect costs as a proportion of total cost would promote a better understanding of the issues among the public, the research community, the Executive Branch, and Congress.

2. Establishing multi-year fixed rates

A method to reduce complexity

In order to reduce complexity and cost, all cognizant agencies should adopt five-year indirect cost rates. For the base year, each university would prepare a detailed cost rate proposal, which would then be audited and a fixed rate negotiated for a five-year period. There would be a subsequent audit of the base year, and annual audits performed under OMB Circular A-133 would include procedures to assure consistency of accounting policies, adequacy of the internal control structure and appropriateness of the amounts included in the annual indirect cost studies.

Eighteen months before the original agreement is due to expire, the process of making a new proposal, having it audited, and negotiating a rate should begin. This would allow both researchers and federal agencies to have an accurate picture of future rates and would therefore aid them in seeking appropriate funding levels.

A system of multi-year fixed rates would have several major benefits. First, it would establish a new degree of fiscal discipline that would reinforce incentives for universities to contain their costs over a five-year span. The knowledge that the negotiated rate is essentially immutable would naturally stimulate additional cost management efforts at the local level. Second, it would eliminate uncertainty in the cost rate, thereby giving universities a fixed range of reimbursement and assisting them in

predicting future revenues and expenses. Third, it would eliminate carryforward adjustments, which are difficult to predict and often give misleading information about a university's current costs.

Fixed rates could be changed under extreme conditions

The indirect cost rate for each university will remain unchanged for five years. As direct costs fluctuate, indirect cost reimbursement will automatically adjust. However, a dramatic change in conditions, such as increased or decreased direct cost activity exceeding 15 percent of base year activity in a single year, major changes in facilities, or catastrophic events, could result in a rate alteration. The A-133 audit procedures can be used to monitor direct research volume and such major changes.

3. Combining costs pools and setting rules for them

In order to simplify the process of indirect cost accounting, the present seven cost pools used in accounting for research costs should be combined into three:

- **Administrative costs** — This pool will contain costs currently in the General and Administrative, Departmental Administration, Sponsored Projects and Student Services cost pools.
- **Operating costs** — This pool will contain the current Operations & Maintenance and Libraries cost pools.
- **Capital costs** — This pool will be similar to the current Depreciation cost pool.

Each of these new cost pools is described in detail below:

Administrative costs

The present 26 percent cap arbitrarily applied to all institutions is neither equitable nor consistent with the concept of reimbursement based on actual cost. Under our proposal, the present 26 percent cap on administrative expenses would be replaced with a newly determined "threshold rate" on administrative costs.

Institutions accepting the threshold rate would not be required to do expensive and detailed cost findings for administrative costs, thereby saving money for both the universities and the government. Those institutions whose actual costs can be demonstrated to be above the threshold and who wish to be reimbursed for them would be required to document all such administrative charges. The appropriate rate of reimbursement would be determined according to the A-21 cost principles. The 1988 Pings Committee report endorsed the creation of threshold rates, observing that they would "provide simplification and removal of contention."

The threshold rate should be designed to reflect the actual administrative costs for *similar* universities based on actual cost. For example, large private research institutions

could be grouped together. The present 26 percent cap groups together all universities, which are quite *dissimilar* to one another.

Operating costs

Operating expenses would be subject to periodic cost-analysis studies. The primary purpose of such studies is to determine how indirect costs of research differ from indirect costs of instruction. The cost of operating laboratories is proportionately far greater than the cost of supporting classrooms. Therefore, cost-analysis studies to determine research-related costs should be encouraged so that costs can be fairly allocated. Significant differences among universities — such as location, facility use and density, research mix, and governance structure — also suggest that cost-analysis studies are needed to determine costs accurately and equitably.

As for libraries, in lieu of permitting each university to develop its own allocation methodology, we propose that a limited number of methodologies be developed regarding library allocation costs. Each university should use the methodology which most appropriately fits that institution.

Capital costs

Since the government does not cover the up-front costs of constructing facilities for government-sponsored research, reimbursement mechanisms should be found to closely match universities' cash flows. We support the recognition of shorter, more realistic useful lives in the development of depreciation schedules and use allowances, as suggested in the 1986 report of the White House Science Council.

Furthermore, we support the recent efforts by OMB to ensure that depreciation reimbursement be used to support research facilities. These funds should not be segregated, due to the administrative, accounting and auditing burdens that would result, but universities should demonstrate that an amount equivalent to reimbursement for depreciation is actually invested for research facilities during an agreed-upon interval of time (e.g. five years).

Administrative costs could be substantially reduced if the level for capitalization of equipment were raised from five hundred dollars. The outmoded threshold level raises the amount of effort required, but does not significantly raise the level of accountability. The five hundred dollar threshold was instituted in 1969, and has not been increased despite years of inflation.

We suggest that capital costs be reimbursed based on individualized cost-analysis studies because equipment and buildings are going through a period of rapid change in technology and programmatic content. Uniform, prospective payment for facilities costs would not be practical at universities due to the enormous variability in physical plants caused by construction standards established to mitigate events such as earthquakes and extreme temperature variations.

4. Defining the role of cognizant agencies and an appeals process

Clearer principles and regulations are needed regarding the standards to be applied by universities and cognizant agencies. A speedy, independent appeal mechanism for universities is also essential. Our primary concern is that there be an even-handed application of the cost principles of A-21.

A formal, independent, and responsive appeal mechanism must be established as part of the overall process. At the moment, appeals may take many years to resolve and do not adequately deter the arbitrary judgments of negotiators. The proposed appeals process would provide the right amount of flexibility, since universities could take their differences to another government body for review of decisions. The appeals process will ensure that the two major cognizant agencies do not diverge in their application of A-21.

Conclusion

In short, the basic principles underlying A-21 are sound and should be maintained, but some streamlining of the indirect cost reimbursement process would improve the efficiency and general understanding of the system. To that end, we propose creating a system of five-year rate agreements, combining cost pools, and establishing an independent appeals process that will guarantee the rights of both the universities and the federal government. To increase the important matter of public understanding, we propose redefining the expression of indirect cost rates.

As the structure of indirect cost reimbursement changes, it is critically important to all involved that the enormously valuable partnership between the government and universities not be impaired. We hope that our proposals, and those of our sister institutions and representatives of the federal government, can lead to broad areas of agreement on which to make adjustments so that this long-term, mutually beneficial partnership can continue to sustain America's preeminence in basic research.

"Document Control"

TYPE: INFORMATION DOCUMENT NUMBER: 9202709
ORIGINATOR: 02 STATUS C DIRECTORATE STATUS

FROM: MASSEY, WALTER E.: NATIONAL SCIENCE FOUNDATION

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/11/92

SUBJECT: COPY OF A LETTER TO SENATOR TRENT LOTT THANKING HIM
FOR HIS LETTER OF JULY 6, 1992 RECOMMENDING JOE
THOMPSON FOR THE HIGH PERFORMANCE ADVISORY
COMMITTEE.

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley
PCAST
INDUSTRIAL

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FILE: P-PCAST
CENTRAL FILES:

2709

NATIONAL SCIENCE FOUNDATION

1800 G STREET, N.W.
WASHINGTON, D.C. 20550



OFFICE OF THE
DIRECTOR

August 11, 1992

Honorable Trent Lott
United States Senate
Washington, D.C. 20510

Dear Senator Lott:

Thank you for your letter dated July 6, 1992 recommending Dr. Joe Thompson for the high performance advisory committee. This advisory committee is being assembled by the President's Office of Science and Technology Policy (OSTP) under the authority of the High Performance Computing Act of 1991 (P.L. 102-194).

I have taken the liberty of forwarding your letter, along with the enclosure regarding Dr. Thompson, to Dr. Allan Bromley, the President's Science Advisor and Director of OSTP for appropriate consideration.

Thank you very much for contacting me and if I can provide you with any additional information on this matter, please let me know.

Sincerely,

Walter E. Massey
Director

cc: Dr. Allan Bromley

"Document Control"

TYPE: ACTION

DOCUMENT NUMBER: 9202409

ORIGINATOR: 02

STATUS I

DIRECTORATE STATUS

FROM: JACOBSON, John: HOPE COLLEGE

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/10/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

SENDER'S DUE DATE:
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HOPE COLLEGE

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OFFICE OF THE PRESIDENT
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92 AUG 18 P 1: 04

OSTP
MAIL ROOM

August 10, 1992

Mr. D. Allan Bromley
The Assistant to the President
for Science and Technology
PCAST
The White House
Washington, DC 20500

Dear Mr. Bromley:

On June 8 you sent an invitation to submit written comments on the topics being considered in the current round of public meetings. This is my response to that kind invitation.

While Hope College is not a research university, we pride ourselves on the number of our graduates who go on to take advanced degrees in science at research universities. We pride ourselves, too, on the extent to which we are able to involve our undergraduate students in original laboratory research projects, working collaboratively with professors and other students. We believe that experience of serious laboratory research at the undergraduate level is an important component in the education of future scientists.

The future of science in our research universities and in the nation depends upon a satisfactory supply of well-prepared and well-motivated students. We need to draw upon a wide range of talent, Americans as well as international students, women and minorities as well as majority men. Research universities and the Federal government must give thought and attention to undergraduate education in science. There are, therefore, two recommendations that I would like to make to you and to PCAST:

1. Attention and support should be given to undergraduate science education. Encouragement should be given to undergraduate institutions, such as those in the Oberlin group, which provide an active research environment for their students and which send many graduates into careers in science.

Mr. D. Allan Bromley

PCAST

August 10, 1992

Page two

2. Research universities should be encouraged to devote more of their attention to the preparation of undergraduates by developing research opportunities for their own undergraduate students and by involving research professors in teaching.

Recent studies have shown that there is a group of small liberal arts colleges, like Hope College, that regularly send a significant number of graduates into careers in science. I hope that PCAST will remember and support these institutions along with the research universities.

Thank you for the opportunity to comment.

With all good wishes,



John Jacobson

mp

JJ-10.10

"Document Control"

TYPE: INFORMATION

DOCUMENT NUMBER: 9202428

ORIGINATOR: 02

STATUS C

DIRECTORATE STATUS

FROM: CROWE, LAURA: GLAXO RESEARCH INSTITUTE

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/07/92

SUBJECT: COPY OF THE PRESENTATION OF THE PCAST MEETING
07/21/92

DIRECTORATE
ASSIGNED:

STAFF
ASSIGNED:

ACTION
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STAFF
ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE:
DATE COMPLETED:

STAFF DUE DATE
DATE COMPLETED/DEPT:

COPIES TO: PCAST
D. Allan Bromley

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EXT:

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OSTP RECEIVED: 08/19/92
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CENTRAL FILES:

2428

Glaxo Research Institute

Division of Glaxo Inc.

James Nidel, M.D. Ph.D.
Senior Vice President and Director

August 7, 1992

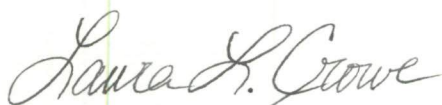
D. Allan Bromley
The Assistant to the President
for Science and Technology
Executive Office of the President
Office of Science and Technology Policy
The White House
Washington, D.C. 20508

RECEIVED
22 AUG 18 10:14
OSTP
MAIL ROOM

Dear Mr. Bromley:

As requested in your July 15 letter, attached is a copy of the presentation given by Dr. James E. Nidel at the July 21 President's Council of Advisors on Science and Technology Public Meeting held at Duke University.

Sincerely,



Laura L. Crowe CPS
Executive Assistant to
James E. Nidel, M.D., Ph.D.

llc

Attachment

**The President's Council of Advisors on Science and Technology
Public Meeting, July 21, 1992, Duke University
Presentation by James E. Nidel, M.D., Ph.D.**

I'd like to take a few minutes this afternoon to describe the three-way partnership that exists between the university, industry and government. This partnership is essential because it will insure stable support of American biomedical science and because it will take basic discoveries and develop them in a way that will benefit society.

But before describing that three-way partnership in more detail, let me comment on the relationship between government and the university. This morning, we emphasized difficulties in the relationship; inadequate participation of women and minorities, decreased levels of support, a decaying infrastructure and declining morale. And while these problems exist, it's important to remember that support of the university is one of the most successful of all government initiatives. American graduate and undergraduate education and American basic research are the best in the world because of the partnership. Our goal is to build on that success.

Now let me return to the three-way partnership between the university, government and industry.

Slide 1

I've placed the university on the top of this triangle because most discoveries of fundamental biomedical importance occur in university laboratories. Fundamental questions are pursued and often fundamental answers emerge. Additionally, university laboratories are the training ground for the next generation of scientists, so

the success of the university laboratory is essential to the future of biomedical research.

Industry and government form the base of the triangle because they provide financial support for biomedical research and development. We in industry support science because we believe that that investment will yield products in the future. But why does government support science?

Slide 2

Government supports science for two main reasons. First, as a species we are defined in part by an innate curiosity; the need to understand our world and our place in it. This need drives the exploration of space, of matter and the workings of a cell. Government recognizes this curiosity and attempts to satisfy it through sponsored research programs. This is an intangible, but important component of an advanced society.

Second, government attempts to improve the quality of our lives through support of science. Emphasis is placed on health, but agriculture, energy and other areas receive significant support as well. And in a world increasingly dependent on technology, this support provides the foundation for a healthy economy. Here society expects tangible results; a healthier life, a cleaner environment or a more efficient workplace.

Scientists in the pharmaceutical industry work toward the second goal. We strive to improve quality of life by discovering and developing medicines that treat disease, alleviate pain or prolong a productive life.

Slide 3

But this can only be accomplished in partnership with university-based scientists. This partnership is necessary because the majority of industry-based scientists pursue applied, rather than basic research. Thus, industry looks to the university for basic discoveries or technologies to build upon. And this technology transfer is crucial, because discoveries which remain within the university may not be developed and may have little impact on quality of life.

Slide 4

Technology is transferred in three general ways. The most common is publication. A large body of knowledge is built by scientists around the world and this knowledge base is then freely available to other scientists for application without restriction. This is the best method for dissemination of information, but it may not be the best method for technology transfer, because if a discovery is not protected by a patent, industry may not pursue its development.

A more recent approach to technology transfer is formation of a new company specifically founded to commercialize the discovery. The entire biotechnology industry is based on this principle.

Slide 5

Large, well established companies will often form partnerships with the new companies, to speed development. At Glaxo, we have formed three such partnerships in the last two years. Gilead Sciences explores code-blocker technology as a mechanism to regulate gene expression and thereby treat cancer and other diseases. Scientists at ICOS have cloned tissue-specific phosphodiesterases which serve as targets for a Glaxo medicinal chemistry program. And Amylin Pharmaceuticals

pursues a pathophysiologic role for a newly discovered pancreatic hormone called amylin. In each case, Glaxo scientists work directly with scientists from the new company to achieve shared objectives.

Slide 6

Our partnership with Gilead Sciences is illustrative. Gilead was founded in 1987, based on fundamental discoveries of mechanisms of gene regulation from scientists at Harvard, California Institute of Technology and the Hutchinson Cancer Research Institute. These scientists had done pioneering work in the chemistry and biology of anti-sense oligonucleotides and founded Gilead to develop the medical applications of those discoveries. Gilead has raised over \$120 million in support of the venture and now employs over 100 scientists. Currently, 30 Glaxo scientists and 30 Gilead scientists work together to solve problems of oligonucleotide stability, cell permeation and bioavailability. These problems must be overcome before the full potential of this technology can be realized.

This is a true partnership, with both groups pursuing a shared objective and sharing ideas and data freely. As this example illustrates, a new company provides an excellent mechanism for transfer of a basic research discovery into the marketplace.

Slide 7

But not all discoveries can be handled by this mechanism. Obviously, the discovery must have sufficient market potential to attract investment, the scientists must want to form a company and investors willing to risk their money must be available.

But meeting all of these criteria is not common. The thousands upon thousands of discoveries that have occurred in U.S. biomedical laboratories have spawned only a few hundred new companies.

Slide 8

Development of other discoveries depends upon a university-industry partnership. But this is not always easy, because the missions of the university and industry are clearly different. University scientists pursue questions of fundamental importance without regard to commercial prospects, (Slide 9) whereas industry-based science is directed towards meeting specific needs for the benefit of society and the shareholders.

Slide 10

To generalize, the university wants funding, while industry wants know-how and patents. Success of the partnership depends on achieving these goals in a mutually beneficial way. This has proven difficult because the university and industry often cannot agree upon a common objective. Frequently, we are unable to bridge the boundary between basic and applied research. The university scientist prefers to continue to pursue the fundamental question, whereas the industry scientist finds the fundamental question irrelevant and wants to move ahead with product development. These positions reflect the different missions of the two institutions and are therefore firmly held and reinforced within each environment. But society expects us to work through these differences and produce the tangible results I mentioned earlier. The university and industry must attempt to find shared objectives that will bring discoveries from the university laboratory into the marketplace. But this must be done in a way that doesn't alter the basic mission of either the university or industry.

The purposes of the university and industry are synergistic. Basic research is largely pursued in the university, whereas applied research is the primary activity in industrial laboratories.

Slide 11

When combined, basic and applied research can lead to developments that improve quality of life. If structured appropriately, university-industry partnerships are mutually beneficial, and arguably necessary if the U.S. is to maintain its leadership role in biomedical research and development.

Slide 12

I'd like to close with this quotation from Sir Isaac Newton, "(I) stood on the shoulders of giants and hence could see a little farther." Newton was explaining how his own discoveries were based on the work of scientists who had preceded him. In the same way, we within industry often stand on the shoulders of our colleagues in the university, and together, we both see a little farther.

Improving mathematics and science education in America has emerged as a major concern of the nation's opinion leaders. That is why I thought you would be interested in the variety of support to education provided by one of your federally funded centers of research and development.

A handwritten signature in dark ink, appearing to read "Alan Schriesheim". The signature is fluid and cursive, with a prominent initial "A".

Alan Schriesheim, Director and CEO
Argonne National Laboratory

Document Originally
Attached to
Following Page

"Document Control"

TYPE: INFORMATION

DOCUMENT NUMBER: 9202387

ORIGINATOR: 02

STATUS C

DIRECTORATE STATUS

FROM: SCHRIESHEIM, ALAN: ARGONNE NATIONAL LABORATORY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/06/92

SUBJECT: PHOTOGRAPHS OF DR. BROMLEY AT ARGONNE- ENCLOSED
PUBLICATION DESCRIBING EDUCATIONAL PROGRAMS

DIRECTORATE
ASSIGNED:

STAFF
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OSTP DUE DATE:
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STAFF DUE DATE
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COPIES TO: D. Allan Bromley
INTERNATIONAL/POLICY

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OSTP RECEIVED: 08/14/92
FILE: P-EDUCATION

DEPT RECEIVED:

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ARGONNE NATIONAL LABORATORY

9700 SOUTH CASS AVENUE, ARGONNE, ILLINOIS 60439 - 4832

2387
Office of the Director

August 6, 1992

Dr. D. Allan Bromley, Director
Office of Science and Technology Policy and
Assistant to the President for Science
and Technology
Old Executive Office Building
Washington, D.C. 20506

Dear Allan:

It was a pleasure to have you at Argonne again, to show you some of our work in progress and to give our staff a chance to hear your colloquium address.

To have a knowledgeable, interactive scientist like you talk with our people helps to renew faith throughout the Laboratory that science is well represented in the Washington halls of power. I hope you could sense that, as I did, especially in the question and answer period following your colloquium.

Enclosed are a few photo mementos of the day. I'm also including a publication describing our educational programs which was published in July, 1991. On the basis of our discussion, we are re-examining the distribution to make sure we cover any areas that we missed on the first distribution.

Thank you again for coming to Argonne.

Very truly,

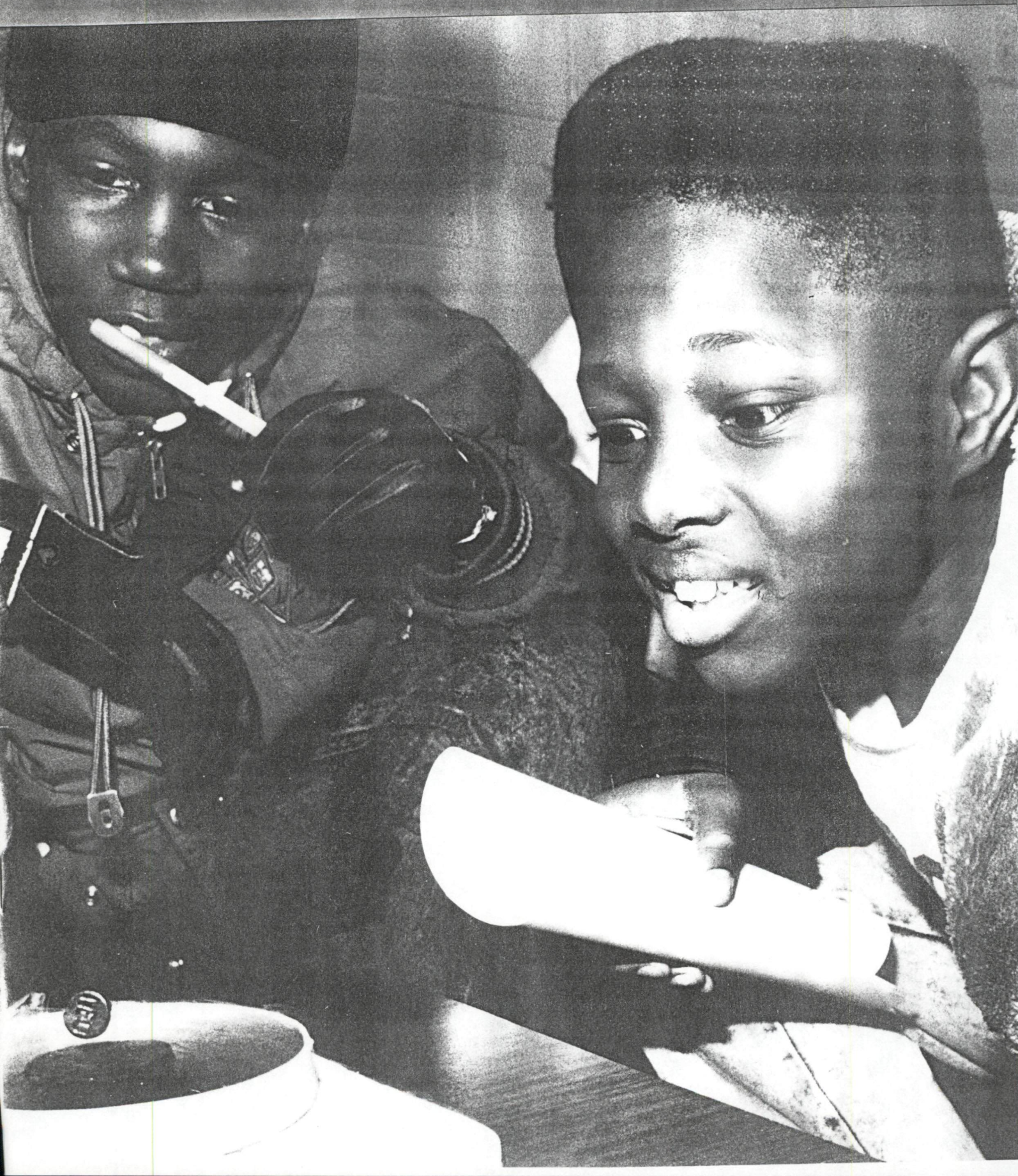


Alan Schriesheim
Director

AS:Hj
Enclosures

Succeeding With Science

Scientific Education Programs
at Argonne National Laboratory



"Document Control"

TYPE: INFORMATION

DOCUMENT NUMBER: 9202385

ORIGINATOR: 02

STATUS C

DIRECTORATE STATUS

FROM: MALONE, THOMAS: SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/06/92

SUBJECT: LETTER REGARDING HOPEFUL COMMENTS CONCERNING THE
NEED FOR FEDERAL FUNDING OF INTERDISCIPLINARY
RESEARCH AND INCREASING ROLE OF STATE FUNDING FOR
UNIVERSITY RESEARCH IN THE PUBLIC INTEREST.

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

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OSTP DUE DATE: STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: PCAST
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D. Allan Bromley

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Sigma Xi, The Scientific Research Society

2385

August 6, 1992

Dr. D. Allan Bromley
Asst. to the President for Sci. & Tech.
Executive Office of the President
The White House
Washington, DC 20500

U.S.T.P.
MAIL ROOM

92 AUG 14 AM 11:50

RECEIVED

Dear Allan:

Your session at Duke on July 21 was very productive.

Further to my remarks at that time, I hope your committee's report will include:

- +Recognition of the need for federal funding of interdisciplinary research where it is needed to address national problems and

- +recognition of the increasing role of state funding for university research in the public interest.

I am delighted that Nancy Maynard will attend our University Colloquium On Environmental Research And Education on September 24-26 which I suspect will touch on inadequacies of federal support for interdisciplinary studies.

With every good wish.

Sincerely yours,

Thomas F. Malone
Director, The Sigma Xi Center

cc: Dr. H. T. Shapiro

"Document Control"

TYPE: ACTION DOCUMENT NUMBER: 9202362
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: GOLDWASSER, Edwin L.: UNIVERSITY OF ILLINOIS

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/04/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND U.S. RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/27/92 STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #: CONTACT PERSON:
PHONE: EXT:

REMARKS: *NRN per AKD*

OSTP RECEIVED: 08/13/92 DEPT RECEIVED:
FILE: P-PCAST

CENTRAL FILES:

University of Illinois
at Urbana-Champaign

Computer-based Education Research Laboratory (CERL)

252 Engineering Research Laboratory 217 333-6210
103 South Mathews Avenue
Urbana, IL 61801
USA

RECEIVED

92 AUG 13 A 9:47

August 4, 1992

OSTP
MAIL ROOM

Dr. D. Allan Bromley
Assistant to the President
Science and Technology
White House
Washington, D.C.

Dear Allan,

I have just returned from vacation to find a copy of your letter of June 8 addressed to our Chancellor, Dr. Morton W. Weir, as well as to other chancellors and presidents of research-intensive universities. I am too late to have my comments included in Dr. Weir's response, and perhaps I'm too late to have my comments receive normal consideration. I hope not.

As I would have expected, your summary of PCAST's broad view of the relationship between research-intensive universities and the federal government is very close to my own. I have two specific suggestions to make. I know that under present practices and economic pressures they will be difficult to implement. However I feel that it is essential that in viewing budgetary pressures a line be drawn between those expenditures that are "operating costs" and those that are "investments in the future" of this nation. I trust that everyone will agree that education and research, two activities that are very closely related, warrant an assignment of the highest priority on any list of investments in the future. Furthermore, it should be abundantly clear that without investing boldly in our future, we can never hope to regain the world leadership that has been ours in the past and thus, for example, to begin to payoff the large national debt that we have accrued in recent years.

My first suggestion is simply that some action be taken to provide a greater degree of stability in the funding of research than is now the case. A few research projects are short-term activities that might even be expected to come to fruition within a single year. However, those are the exceptions. In general, the questions that are posed today at the leading edge of most branches of basic research are ones that require years of preparation, construction of equipment and development of expert staff. Programs of that kind cannot flourish in an environment in which next year's funding level is completely "up for grabs". In order effectively to exploit fundamental research opportunities of this kind, the government must find better ways to make meaningful commitments to long-range programs.

My second suggestion has to do with the need for discretionary funds within any institution involved, in a major way, in the performance of fundamental research. This need has been recognized, in the case of the national laboratories, by every committee that has been appointed to advise the government on ways in which most effectively to exploit the potential of those laboratories. Furthermore, as I understand it, industrial contractors are permitted to include, among their indirect costs, a certain level of expenditure for exploratory work of a nature that supports the development of new ideas and initiatives.

Dr. D. Allan Bromley
August 4, 1992
Page 2

There is a time when the potential development of ideas for productive directions of research is not yet sufficiently well understood to permit a substantive proposal to be placed before an appropriate government agency. Such pre-proposals, however, can be evaluated locally by science administrators who are familiar with the people who are involved and with their track records. In my view an investment by the federal government in a small amount of institutional discretionary funds would have an enormous payoff for the Government and for the nation. It could be sized, as it is for the national laboratories, in terms of a percentage of whatever research activities are actually being funded. The university, however, would not be limited to applying individual packages of such discretionary funds in the areas in which they would be generated. Rather, the institution would be expected to pool all such pieces of discretionary funds and to use them as a single institutional discretionary fund to be used for the support of promising new explorations of possible initiatives. There should be a restriction that no such initiative could be funded for more than some specified period from such funds.

I hope that these ideas may be of some use to PCAST.

Sincerely,



Edwin L. Goldwasser, Acting Director
Computer-based Education Research Laboratory

ELG/eeg

"Document Control"

TYPE: ACTION DOCUMENT NUMBER: 9202363
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: WYATT, Joe B.: VANDERBILT UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/04/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/27/92 STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #: CONTACT PERSON:
REMARKS: *NRN per ARD* PHONE: EXT:

OSTP RECEIVED: 08/14/92 DEPT RECEIVED:
FILE: P-PCAST
CENTRAL FILES:

VANDERBILT UNIVERSITY



NASHVILLE, TENNESSEE 37240

2363
TELEPHONE (615) 322-7311

RECEIVED

Office of the Chancellor • Suite 211, Kirkland Hall • Direct Phone 322-2168

FAX 615-322-3968

92 AUG 14 A10:52
August 4, 1992

OSTP
MAIL ROOM

D. Allan Bromley
The Assistant to the President
for Science and Technology
The White House
Washington, D. C. 20506

Dear Allan:

Thank you for the opportunity to address the importance of the partnership between the Nation's research-intensive universities and the Federal government. The historic partnership between the Nation's research-intensive universities and the Federal government has produced a research capacity that is the envy of the world. In 1873, President Abraham Lincoln signed into law a bill creating the National Academy of Sciences as advisor to the Federal government. In July of 1945, a commission appointed by Franklin D. Roosevelt issued a report entitle SCIENCE -- THE ENDLESS FRONTIER which cited the need to ensure the nation's self-reliance with respect to scientific knowledge.

A few months before his death, President Roosevelt said, "New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness and drive which we waged this war, we can create a fuller and more fruitful employment and a fuller and more fruitful life."

Today, our research infrastructure is the keystone of the America's international competitive edge in the new world order.

To meet the challenges of the future, the partnership must (1) educate the best scientists in the world and provide them with a productive work environment, and (2) connect the best scientific and technological research in the world to the development of a world class educational system for all children and to the demands of the international economy.

My testimony will emphasize three critical components of an effective national strategy: (1) The urgent need to rebuild the research facilities necessary to support the scientific and technological research of the information age, (2) the role of competitive merit review in producing the best science in a

world of limited resources, and (3) the role of the partnership between the Federal government and research-intense universities in connecting scientific and technological research to a world class educational system for all children.

We must modernize our academic research facilities. The deterioration and obsolescence of the nation's science and engineering research facilities is well documented. In 1986, the Packard-Bromley report, issued by the White House Council, cited the need for a 10 year, \$10 billion dollar program. The report was not talking about an improvement program, it was addressing the question of what it would take to put the research infrastructure back to an acceptable condition. These findings were confirmed by NSF's 1990 survey which estimated the price tag had grown to \$12 billion.

Arguments over exactly how many billion is needed or how much we are spending now compared to 20 or 30 years ago are useless. What is needed is a commitment to action. Every year, we fail to move ahead with the job of rebuilding our research infrastructure, we weaken the foundation of our competitiveness and limit our ability to respond to future challenges.

At Vanderbilt, when we made a decision to put the power of computer analysis, data and word processing and electronic telecommunications in the hands of our students, it was not sufficient to buy computers and telephones. It was necessary to redo the electronic infrastructure of the University to support the goals of modernization.

For the laboratories of 1990's and beyond, it is not good enough to purchase expensive instruments. The instruments are essential but they are not useable in many of the facilities built in the 1960's or earlier. These new research instruments require more space per researcher and more sophisticated environments than older facilities afford. Today, even the latest instruments may face early obsolescence and require flexible environments that lend themselves to change and expansion. Even research tools that are widely accepted as standard for today's research require modernization of facilities.

Inflexible and obsolete old buildings are difficult and costly to retrofit. These piecemeal efforts have a short shelf life and fail to take advantage of economics of scale. Many must be replaced or the quality of the research and education programs in laboratories will be compromised.

To further compound the problem, federal, state and local governments are imposing new standards and regulations that require costly compliance. These standards address important issues like the care and handling of research animals, the collection, handling and storage of radioactive,

hazardous and toxic wastes, electrical and fire codes; however, the money spend by research-intensive institutions to meet them subtracts from the funds available to support research. When these standards are applied to existing structures, they render their use for research economically questionable at best.

The neglect of research facilities works against the nation's goal of training the best scientists in the world and providing them with a productive work environment. The cost to a university of setting up a laboratory for a young research scientist is \$250,000 to \$500,000, or substantially more in some cases. The costs of a recognized researcher can easily exceed these sums. These are not optional costs, they are a condition of the scientist's ability to do the research.

The lack of adequate funding for research facilities has created an intensely competitive environment characterized by the growing practice of earmarking by the Congress. More and more institutions have received funds without either a competitive application process or a professional review of the scientific and technical merits of their appeal for federal funds prior to the award of funds. The pressures on the Congress and on universities to engage in this practice have grown enormously.

Analysis of the 1988-89 data cited in the 1990 National Science Foundation (NSF) report, revealed a more than doubling of federal funds for new construction from \$173 to \$413 million. The bulk of the increase, however, was distributed through non-competitive earmarks. None of the increase went to private institutions. As a result, while public institutions show a \$252 million increase in research-related capital funding, the funding for private institutions dropped by \$12 million. Private institutions were further restrained by changes in tax laws, e.g. bond caps and tax credits, in their ability to raise private funds to support research-related capital projects. These factors together result in increased pressure on private institutions to seek earmarked facilities funding.

In spite of determined efforts by some members of Congress to hold the line, the practice is escalating. Senators Nunn and Danforth with the cooperation of representatives of higher education, made a concerted effort in FY 1990 to limit earmarking. They met with some success. The growth curve was reversed and there was a slight decrease in earmarking in FY 1990. But by 1991, THE CHRONICLE OF HIGHER EDUCATION (February 17, 1991) reported appropriations for specific colleges and universities had climbed to an all time high of almost \$500 million. The previous high was \$289 million in FY 1989. In FY 1992, the upward trend continued to more than \$680 million. Not only are the total appropriations higher, but more congressional committees are designating earmarks, more universities are seeking and receiving them (some with the help of professional lobbying firms) and some depend on large annual appropriations from earmarking.

The phenomenon has attracted the attention of the popular media. Both the practice and its notoriety raise doubts in the minds of the public concerning the integrity of the federal/research-intensive university partnership.

The answer is not to try to silence the media or to cast blame, it is to solve the problem. The nation must have a rational, coordinated national policy that includes (1) stable and dependable direct investment in basic research and in the construction and modernization of laboratories through competitive, matching and leveraged federal grant programs and (2) a rational tax policy that promotes private investment in research facilities.

Universities expect to carry their share of the responsibility. This is a partnership. The development of the FEL Center at Vanderbilt represents the best in such research partnerships. Vanderbilt invested \$2.6 million in the facility and recruited an outstanding team of women and men to do the work of the Center. We contracted with a start up company in California to build the laser. The Federal government has committed \$14.6 million to the project. We have all taken risks and shared responsibility.

Finally, research-intensive universities must take responsibility sharing the lessons learned from Federally funded research with colleagues throughout the educational system. At Vanderbilt, we are seeking opportunities to apply new knowledge to the task of building a world class educational system to serve all children.

Researchers have routinely used computers to empower learning for over 20 years. But technologies have been slow to come to the classrooms of American children. For more than 20 years, people involved in television have worked to unleash the power of that medium in educating young people. National Geographic, NASA and many others are continually producing high quality videos. "Sesame Street" has taught countless youngsters to count, recognize shapes and other basic knowledge and very importantly has generated enthusiasm for the life of the mind.

The same 20 years has seen the explosive development of the computer, a development that has literally changed the way America works. Simultaneously, technology has propelled the evolution of telecommunications. Working in concert, computers and telecommunications can create and transmit all types of images and data "live and in color" around the world virtually instantaneously.

At Vanderbilt, through grants provided by the National Science Foundation, we have developed some new ways of capturing the power of

technology and children's affinity for it to tackle one of the most onerous subjects for children -- MATH. And because of the approach we have taken, mathematics is linked naturally to other subjects for which it is critical.

Through "The Adventures of Jasper Woodbury", we have been able to help improve students' mathematics and problem-solving skills. The videodisc series developed at Vanderbilt's Peabody College uses "real-world" story telling format to present complex and interesting problems that students work together to solve. The series promotes the kind of "constructive" mathematical experienced called for by the National Council of the Teachers of Mathematics.

The evaluation of the first year of the series' implementation showed a significant reduction in math anxiety, an increased understanding of the usefulness of mathematics and improved performance on complex math problems. Vanderbilt has teamed up with corporate partners and local school systems to implement Jasper in real classrooms. The series currently is being used by about 225 teachers with more than 5,000 students in a dozen states. Through the power of telecommunications and computer, these 5,000 students compete in learning challenges requiring them to apply what they have to new problems.

Jasper could not have been developed without the support of NSF. Vanderbilt could not have collected the outstanding team of researchers in cognitive studies, psychology, technology and content who worked on the project were it not a research-intensive university. The team interacted with other technical experts on the campus who work to support an array of research endeavors. Jasper is an example of a research effort targeted directly to K-12.

Even large basic research projects can be used to benefit K-12 learners. The Free Electron Laser Center, among the largest research projects undertaken at Vanderbilt, promotes cooperative efforts which take the raw materials of basic science and produce technical solutions to real life problems. The Center is attracting proposals from research scientists from around the world.

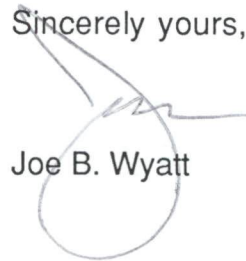
The Center also plays a vital role in educating young scientists for the future and attracting talented students to careers in science, engineering and medicine. Vanderbilt uses the Center to teach high school students about lasers in our Summer Science Collaborative. The Collaborative (funded by Vanderbilt and corporate sponsors) brings Vanderbilt faculty and facilities to high school science students and teachers in Middle Tennessee. They return to their schools fired up about physics.

CONCLUSION

From pacemakers to computer graphics, from computer controlled farm machinery to shop floor robots to handle hazardous materials, research, science and technology are racing the clock of history. This is not a high speed chase for the fascination of elite scientists, it is a race to marshal knowledge and the tools of science and technology to feed the growing world population. It is a race to harness our industrial capacity to increase the standard of living for human beings all over America and all over the world. It is a race to combat disease, to conquer the known enemies like cancer and heart disease and to cope with new disease phenomenon of which AIDS is the most dramatic example. It is the race to understand and control our intrusion into the natural environment before we poison the earth for future generations. The stakes could not be higher. They are death and human suffering. They are life and the opportunities for human development. They include our capacity to sustain a competitive economy in the international marketplace.

I urge the Council and the President to give this partnership the urgent priority it requires.

Sincerely yours,



Joe B. Wyatt

JBW:ce

"Document Control"

TYPE: ACTION

DOCUMENT NUMBER: 9202364

ORIGINATOR: 02

STATUS I

DIRECTORATE STATUS

FROM: OLIVER, Jack: CORNELL UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/03/92

SUBJECT: HE IS FORWARDING HIS COMMENTS ON THE SCIENCE AND
TECHNOLOGY REPORT.

DIRECTORATE

STAFF

ASSIGNED: PATRICK WHITE

ASSIGNED:

ACTION

STAFF

REQUIRED: AS NECESSARY

ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE: 08/27/92

STAFF DUE DATE

DATE COMPLETED:

DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #:

CONTACT PERSON:

REMARKS:

PHONE:

EXT:

OSTP RECEIVED: 08/14/92

DEPT RECEIVED:

FILE: P-PCAST

CENTRAL FILES:



Cornell University

DEPARTMENT OF GEOLOGICAL SCIENCES

SNEE HALL • ITHACA, NEW YORK 14853-1504

TELEPHONE: (607) 255-5267

FAX: (607) 254-4780

August 3, 1992

RECEIVED

AUG 10 1992 A10:52

OSTP
MAIL ROOM

Dr. D. Allan Bromley
The Assistant to the President
for Science and Technology
The White House
Washington, DC 20500

Dear Dr. Bromley,

Thank you for the copy of the President's Science and Technology Report and Outlook, and for the invitation to provide information that might be useful in future reports of this kind. In response, I would like to draw to your attention one matter that, in my opinion, merits special consideration. It is that the United States should greatly expand its efforts to explore, and develop a comprehensive understanding of, the buried portion of the continental crust.

With the exception of the relatively shallow sedimentary basins that hold petroleum, and some scattered sites that have received special attention for one reason or another, the bulk of the continental crust, although very near to us, is poorly-known and certainly deserves to be called a major frontier. That seems incongruous in this marvelous era in which we make fly-by movies of the surface of Venus, observe the tiniest components of the nucleus of the atom, and seek the outer limits of the universe. In any case, we humans are constrained to live on earth, to draw our essential resources from it, to dispose of our wastes in it, and we are subject to the hazards the earth presents. Surely, in addition to probing esoteric subjects, it is in our best interests to learn as much as we can as soon as we can about the part of the earth that sustains us and that is so close to us that we could walk to it if it were not subterranean.

The continental crust is typically about 40 km thick. Geologically, its surface is reasonably well-known. The upper 5 km of the crust is accessible by excavation in mining style, the upper 10 to 15 km may be probed and sampled by drilling. The entire crust may in principle be explored in considerable detail by a combination of various geological, geochemical and geophysical methods.

The methods for exploration of this part of the earth are already available and proven. In particular, industry has developed the techniques of drilling, and of seismic reflection profiling and seismic subsurface mapping, for exploration of petroleum provinces, and it has already been demonstrated beyond doubt that these techniques are effective on the larger scale of the entire crust. This subject is not, of course, completely ignored at present. Some successful but modest efforts to explore the entire crust are already being made by universities, state and federal surveys and other government agencies, but progress is slow, spotty and sporadic. What is needed is a much more comprehensive effort designed to provide in a modest time frame a thorough understanding of the continent.

To give a more quantitative flavor, one might think, for example, of a seismic reflection survey of a grid spaced at intervals of, say, 100 km and spanning the United States. Such a survey might require the services of ten seismic crews operating for 5 years at a cost of perhaps \$3

x 10^6 /crew/yr., for a grand 5 year total of $\$150 \times 10^6$. Skilled crews and modern equipment are readily available in the petroleum industry. A deep drilling program to test and calibrate the seismic results and collect deep geological samples might require a comparable sum.

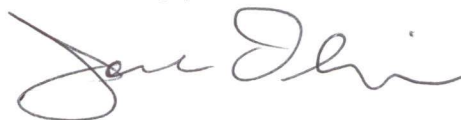
Such a program, when integrated with known surface geology, would provide the basis for understanding the formation and structure of the continental crust. It would also provide basic information to aid in the search for petroleum and mineral resources and to guide us as we make decisions on where to store wastes, how to use fluids of the crust, and how to live with earth hazards.

In earthquake-prone areas, such as California for example, and in conjunction with geological and earthquake-based seismological data, such seismic surveys would provide scientists with a geological understanding of the crust - what is there, how it works, and why earthquakes occur as they do. It is a sign of neglect, or oversight, and almost irresponsibility, that we have not yet collected such readily obtainable information for the entire region of the recent California earthquakes that, in the minds of many seismologists, are forerunners to "the big one" that we all know will, sooner or later, strike that state.

The accumulation of fundamental knowledge on the great subterranean parts of the continents is a logical next step in the history of exploration of our planet. It is a step analogous to the thorough geographical exploration of North America that followed the early forays of Columbus and other explorers, and analogous to the thorough exploration of the sea floor in the post WWII era that brought us the astonishing concept of plate tectonics. Humans have profited enormously from those great eras of exploration of the past. The buried continental crust is the frontier that provides the opportunity for yet another giant step.

Let me close by noting that this letter is rooted in conviction and not self-interest. Although the subject is my specialty, I am nearing retirement age and I do not stand to profit either personally or professionally from a program of accelerated exploration of the continents. I make my point because it is the whole of society that stands to benefit from the proposed effort.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Jack Oliver", with a stylized, flowing script.

Jack Oliver
Irving Porter Church
Professor of Geology

JO/kav

"Document Control"

TYPE: ACTION

ORIGINATOR: 02

DOCUMENT NUMBER: 9202365

STATUS I

DIRECTORATE STATUS

FROM: McPHERSON, Mary Patterson: BRYN MAWR COLLEGE

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/03/92

SUBJECT: SHE IS FORWARDING HER COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESERACH INTENSIVE UNIVERSITIES.

DIRECTORATE

ASSIGNED: PCAST

STAFF

ASSIGNED:

ACTION

REQUIRED: AS NECESSARY

STAFF

ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE: 08/27/92

STAFF DUE DATE

DATE COMPLETED:

DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #:

CONTACT PERSON:

REMARKS:

PHONE:

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OSTP RECEIVED: 08/14/92

DEPT RECEIVED:

FILE: P-PCAST

CENTRAL FILES:

2365
RECEIVED
B R Y N M A W R

92 AUG 14 A10:55

August 3, 1992

Dear Dr. Bromley,

OSTP
MAIL ROOM

I was very reassured to know, from a conversation with Peter Likins, that the scope of the President's Council of Advisors on Science and Technology will extend beyond the research-intensive universities and concern itself as well with those liberal arts and undergraduate colleges that play such a disproportionately large role in educating this nation's scientists.

As you are surely aware, any examination of the partnership between education and government in creating and supporting young scientists needs to focus on the overall process by which students choose advanced studies and careers in science. The pool of future research scientists is most certainly created at the undergraduate level, and most especially at those undergraduate institutions which take a special interest in training creative researchers. For instance, we know that colleges like Bryn Mawr that support both graduate and undergraduate programs in the sciences play a unique role in supporting the nation's overall efforts in these fields.

- As undergraduates women are two to three times more likely to major in the natural and mathematical sciences when they attend a women's college;

- Nearly 30% of all undergraduates here at Bryn Mawr major in the sciences, and 80% of those majors subsequently attend graduate and medical schools.

- Recently we found that Bryn Mawr College alone (with fewer than 300 baccalaureates a year) awarded 1% of all the A.B. and B.S. degrees granted to women in physics nation-wide over the last five years. Bryn Mawr, along with M.I.T. and Johns Hopkins, is among the ten undergraduate institutions which produce the highest percentage of medical school entrants.

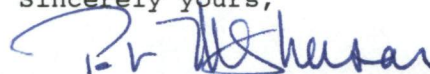
The importance of the undergraduate major lies not only in selecting future scientists but also in laying firm groundwork for creative research. The ability to conduct significantly fruitful research does not appear overnight at the entrance to graduate school but rather is awakened and carefully cultivated during those two years of intensive study with faculty, postdoctoral, and graduate-level researchers who guide the undergraduate science major into colleagueship.

I would like to assure you that I and many of my colleagues would be pleased to be of assistance to you when the President's Council turns

its attention to liberal arts colleges and their role in the nation's research programs.

We shall look forward to seeing the ongoing results of the Council's work.

Sincerely yours,

A handwritten signature in blue ink, appearing to read "Mary Patterson McPherson", with a stylized flourish at the end.

Mary Patterson McPherson

cc: Peter Likins
Harold Shapiro
Arlen Specter
Harris Wofford

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
The White House
Washington, D.C 20500

"Document Control"

TYPE: ACTION

ORIGINATOR: 02

DOCUMENT NUMBER: 9202379

STATUS I

DIRECTORATE STATUS

FROM: YARBROUGH, Karen: UNIVERSITY OF SOUTHERN MISSISSIPPI

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 08/01/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE
ASSIGNED: PCAST
STAFF
ASSIGNED:

ACTION
REQUIRED: AS NECESSARY
STAFF
ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/27/92
DATE COMPLETED: STAFF DUE DATE
DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #:

CONTACT PERSON:

REMARKS:

PHONE:

EXT:

NRN per ARD

OSTP RECEIVED: 08/14/92
FILE: P-PCAST

DEPT RECEIVED:

CENTRAL FILES:



THE UNIVERSITY OF SOUTHERN MISSISSIPPI

VICE PRESIDENT FOR RESEARCH AND PLANNING

02 AUG 14 All: 41

August 1, 1992

OSTP
MAIL ROOM

Mr. D. Allan Bromley
The Assistant to the President
for Science and Technology
Executive Office of the President
Office of Science and Technology Policy
Washington, D. C. 20506

Dear Mr. Bromley:

The University of Southern Mississippi appreciates the opportunity to provide the President's Council of Advisors on Science and Technology with information concerning some of the challenges we perceive to exist for higher education in the coming century as well as the critical nature of a meaningful government partnership with our universities. Input regarding the issues raised by the members of PCAST were solicited from throughout the University, and I am attempting to summarize our predominant concerns for you in this letter. We have also encouraged our science and technology faculty to individually provide you with input where appropriate.

Of primary concern to most faculty in the sciences, technology, and mathematics areas is the fundamental decision as to whether in America we choose to support predominately large research centers dedicated to intense concentration on single issues or whether we continue to support individuals and small groups which work cooperatively on diverse, basic research issues. We would encourage you to continue support for these diverse, geographically dispersed groups of scientists who work in collaborative ways. We believe this approach will continue to serve the cause of productivity in science well, particularly, because we see basic scientific questions today which demand multidisciplinary approaches for solutions.

As you are well aware, the scientific community as a whole has great concern that some of the large initiatives such as the superconducting supercollider project or the human genome project will divert such large sums of research funding from the total pool of support that the diverse, smaller scale individual or collaborative efforts of scientists can no longer be funded. Some of the most recent funding trends of federal agencies have, indeed, moved toward the support of a small number of large research centers. While these centers undoubtedly are serving to produce good science, the diversity of research issues, methodological approaches, and numbers of scientists who can be supported suffers as a consequence of the "centers" approach.

Concern also exists that the movement toward funding these large research centers will rapidly make it impossible to support quality research scientists across the spectrum of research universities in America. We fear that this will result in deterioration of the quality and quantity of persons who are prepared to assume technology-based or research-based positions in America's work force. We hold strongly to the belief that research represents the highest form of learning. As a result, it is important to the education of our students in the sciences, technology, and mathematics that their learning experiences be led by faculty who are actively engaged in research. We believe that this affords the faculty a currency of knowledge which would not accrue otherwise. Of equal concern would be the fact that we would simply no longer be able to recruit and retain research faculty without the competitive research support which is available from federal programs.

Economically deprived areas such as ours have also now realized that the future development of the region depends to a large extent on our ability to attract industries which depend upon research universities for collaborative research support. Thus, the strength of our science and technology academic programs assumes special importance from an economic development perspective. We believe that it, therefore, becomes especially important that America's science policy emphasize a strengthened partnership among academe, government (state and federal), and industry. We are actively encouraging our faculty to become increasingly involved in technology transfer for the benefit of the general public. Greater emphasis must be placed on the removal of barriers to commercialization in academe and industry, for we believe that basic research remains a highly productive product of government support, but as a nation we have been less successful in moving basic knowledge into applied research and successful commercialization. We would encourage PCAST to use its efforts to strengthen the partnership between industry and academe in order that the gap between basic research and commercialization be bridged.

The strength of the science in this nation is no greater than the potential of our individual scientists. We can, therefore, ill afford to waste the expertise of any of our nation's scientists. We are simply not rich enough in this nation or the world to waste human capital. As a result, our federal agencies must continue to be encouraged to support programming which seeks to recognize and maximize this human potential wherever it exists. In particular, initiatives such as the National Science Foundation's Experimental Program to Stimulate Competitive Research (EPSCoR) and the EPSCoR-like programs which have been developed in other agencies should be encouraged and supported. Developing research universities in geographic areas such as ours must be encouraged and given an opportunity to strengthen the base of their competitive research programs.

We support the peer review system which exists in many funding

agencies, but we also believe strongly that the human potential in individuals which exists in universities and states such as ours is as great as that at the so-called elite institutions of higher learning in this nation. They must be given the opportunity to develop the "reputations" in science which are necessary to reach the competitive "playing fields" in the peer review process. Too often, the "objective" review which is supposed to result from the peer review process is manifestly not blind to bias relative to knowledge of an institution's reputation or to lack of knowledge of the institution. We would, therefore, encourage federal agencies to improve this aspect of the peer review process.

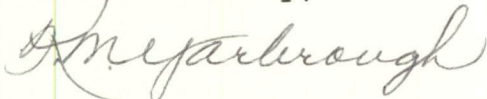
Numerous studies have more than adequately depicted the declining state of our universities research facilities and equipment. With the ever escalating costs of higher education, we must look to the federal government for assistance with a strategy for implementing a broad-based renewal of our infrastructure. While the general public appears more disenchanted with science and her scientists, we believe that we need a concerted effort to educate the lay public about the benefits of investing in our programs for the long-term benefit to society.

Disenchantment of the public with science is a critical issue in itself. As scientists we must individually and collectively repair the image which this nation has regarding our endeavors. Such an effort on our part will be immeasurably strengthened by active support from the President, and we encourage there to be developed a program of support at local levels.

There are but a few of the many issues facing this nation in the development of its science and technology policy for the next century. Some of these have been brought to your attention through others on our faculty, and I will not, therefore, repeat them here.

Thank you again for the opportunity to provide input to the recommendation process which you have developed. We hope that this information will be valuable to PCAST as it formulates recommendations for the President relative to science and technology policy. If we may be of further assistance, please feel free to contact us.

Yours sincerely,



Karen M. Yarbrough, Ph.D.
Vice President for Research
and Planning

xc: Dr. Aubrey K. Lucas
President

"Document Control"

TYPE: ACTION

DOCUMENT NUMBER: 9202367

ORIGINATOR: 02

STATUS I

DIRECTORATE STATUS

FROM: MOBLEY, William H.: TEXAS A&M UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/31/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESERACH INTENSIVE UNIVERSITIES.

DIRECTORATE

STAFF

ASSIGNED: PCAST

ASSIGNED:

ACTION

STAFF

REQUIRED: AS NECESSARY

ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE: 08/27/92

STAFF DUE DATE

DATE COMPLETED:

DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #:

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REMARKS:

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FILE: P-PCAST

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31 July 1992

Office of the President
William H. Mobley

Dr. D. Allan Bromley
The Assistant to the President for
Science and Technology
Executive Office of the White House
Washington, D.C. 20500

Dear Dr. Bromley:

I am pleased to share with the President's Council of Advisors on Science and Technology (PCAST) observations by our faculty on issues that should be considered in a review of the university-government partnership .

The Distinctive Role of the Research University

There must be a strong affirmation by the federal government that it is in the national interest to promote and support the expansion of knowledge and to use this knowledge to tackle the full range of problems that bedevil modern society. Research universities play a distinctive role in realizing this interest by providing graduate education, facilities, and the intellectual climate required to advance knowledge. As a society we seem to have lost sight of this fundamental interest and allowed our focus to shift to details of accountability, budgets, and a proliferation of red-tape. Faculty complaints about red-tape, rules and regulations, micromanagement, and the time devoted to preparing and administering research proposals is one consequence of this shift. Another example is the effort to set limits on researchers salaries through ceilings or the amount of time supported on federal grants and contracts. I also note a strong sense of frustration among our faculty at the absence of strong advocates for research at the federal level. It appears that evaluations of the role and contributions of research to society have been ceded to accountants and lawyers. Positive approaches involve expansion of the Federal Demonstration Project, sunshine provisions for federal regulations affecting research universities, expanded support for public understanding of science programs, and continued close collaboration between universities and the executive branch in setting policies which affect the distinctive missions of the research university.

Dr. D. Allan Bromley

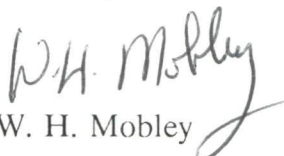
31 July 1992

Page 3

executive branch have emphasized restrictions on the production and dissemination of information collected by or with federal support. Policies have also provided a decreased federal role in ensuring access to information for all citizens. In short, control of scientific and technical information produced by the federal government and academic research institutions is shifting from public to private hands. These changes are likely to have profound affects in the ability of institutions to obtain the information they need to support research activities. Such policies do not support the university's research mission.

I Commend the Council on its timely effort to review the special partnership between the federal government and the research university. I hope to be kept informed about the direction and progress of this important endeavor.

Sincerely,


W. H. Mobley

cc: Dr. E. Dean Gage
Dr. William Merrell, Jr.
Dr. Robert A. Kennedy
Mr. Feenan D. Jennings

"Document Control"

TYPE: ACTION
ORIGINATOR: 02

DOCUMENT NUMBER: 9202404
DIRECTORATE STATUS

STATUS I

FROM: HANSON, Robin: NASA AMES RESEARCH CENTER

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/31/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND U.S. UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 09/01/92 STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #: CONTACT PERSON:
REMARKS: PHONE: EXT:

NRN per AKD

OSTP RECEIVED: 08/18/92 DEPT RECEIVED:
FILE: P-PCAST

CENTRAL FILES:

July 31, 1992

President's Council of Advisors on Science and Technology, and
D. Allan Bromley, Assistant to the President for Science and Technology
Office of Science and Technology Policy,
744 Jackson Place, NW., Washington DC 20506

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SEP 1 1992

OSTP
MAIL ROOM

Dear Dr. Bromley and other P.C.A.S.T. members,

I applaud your current efforts to "seek input from many sources" on how to "'retune' institutional roles and relationships ... between the Nation's research-intensive universities and the Federal government". Indeed "much has changed" since "that relationship was forged a half century ago", and a more fundamental review is perhaps overdue.

Current storms will probably blow over, and cosmetic changes may suffice to preserve business-as-usual for up to another half century. Even so, I urge you to spend some fraction of your time considering the possibility of more radical change. The winds of change often come suddenly, and with gale force, rewarding those who considered their options when the wind was light. A more fundamental review of the relationship between citizens and those they pay to do basic research must reconsider, not just the average grant size or the number of reviewers, but the basic idea of proposal peer review.

The most basic institutional issue, in science and elsewhere, is *accountability*. U.S. taxpayers are the ultimate funders and beneficiaries of federally-funded research. Researchers, research administrators, and federal oversight agencies are supposed to act as "agents", being paid to seek what is in the best interest of their taxpayer clients. As in most walks of life, clients are concerned that these agents will act in their own best interest, instead of that of the clients. To encourage agents to be accountable to their clients, contracts and institutions are formed, structuring the communication and rewards of their participants.

Yet federal proposal peer-review of research is not a particularly accountable institution. To whom do the researchers account, once they have been awarded funding? To whom do the peers who review account, so that they are discouraged from indulging old-boy networks and other conflicts of interest? To whom do the federal administrators account for their bets on which fields are most promising? Yes, the voters could reject the party in power, if their life is not as full as expected twenty years later, but this feedback is terribly weak.

Now managing basic research is notoriously difficult, so one might be excused for suspecting that nothing better is possible. But in fact science has been funded

through a rather wide variety of institutions down the centuries and around the world, many of which seem substantially more accountable than proposal peer-review. Let us draw on this history, on models from related areas of human endeavor, and on our growing understanding of institutional theory and the research process, to explore alternative ways we might fund research.

One particularly robust strategy for structuring state institutions, is *privatization*. Private organizations compete to gain rewards based on well-defined performance criteria. For example, if a city council can define what it wants in terms of local trash collection, this task can be assigned to the lowest-bidder who agrees to follow this definition. In this case, the client need only notice whether the trash is being collected as defined, and can ignore most other aspects of its agent's behavior.

One way to privatize science funding is *prizes*, and in fact prizes were a dominant science funding mechanism from one to three centuries ago. If we want a human genome sequenced, we just offer a prize of so many cents a base-pair, awarded to any private party which first sequences, and publishes, any part of the genome. Prizes work well for any specific achievement which you can foresee wanting to have happen, and for which one can easily determine who was responsible.

But often what you know you want is to eventually get an answer to a certain question, such as the age of the universe, even if you can't foresee what specific achievements will contribute to it. In this case, you might subsidize a *betting market* on that question. Private research groups would then compete to predict which answer to the question will eventually become widely accepted. Of course this approach hasn't been tried much, and is currently illegal in the United States. A paper of mine on the subject is enclosed.

Are such radical alternatives to current institutions really feasible? We won't know unless we try them somewhere and compare. And we should try; getting more research bang for our buck would not only please the patrons, but increase demand for the research product.

Sincerely yours,



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COULD GAMBLING SAVE SCIENCE?

Encouraging an Honest Consensus

by Robin Hanson

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The pace of scientific progress may be hindered by the tendency of our academic institutions to reward being popular, rather than being right. A market-based alternative, where scientists can more formally "stake their reputation", is presented here. It offers clear incentives to be careful and honest while contributing to a visible, self-consistent consensus on controversial (or routine) scientific questions. In addition, it allows patrons to choose questions to be researched without choosing people or methods. The bulk of this paper is spent examining potential problems with the proposed approach. After this examination, the idea still seems plausible and worth further study.

INTRODUCTION

After reviewing the discrepancy between what we want from academic institutions and what we get from current institutions, a market-based alternative called "idea futures" is suggested. It is described through both a set of specific scenarios and a set of detailed procedures. Over thirty possible problems and objections are examined in detail. Finally, a development strategy is outlined and the possible advantages are summarized.

THE PROBLEM

The Scientific Revolution Four centuries ago, some Europeans complained that the existing academic institutions were biased against them. Insiders, it was said, were "inflated by letters" and shunned anyone who dared "speculate on anything out of the common way" [De]. Outsiders -- astrologers, chemists, and people like Bacon and Galileo -- argued that they and their theories should be judged by how well they agreed with observations, and not by how they agreed with the authorities of the day [Gal]. This was the age of utopias [Whi], as these rebels debated possible academic reforms and imagined whole new social institutions, for both academia in particular and society in general.

Within a century or so, the intellectual descendants of these outsiders became the new insiders in a process now called the "Scientific Revolution". They introduced a new respect for observations

along with new social institutions, such as the Royal Society of London, inspired by those utopian ideals. Since then science has made impressive progress. Most controversial issues of four centuries ago seem long settled by now, and continued research may well settle most of today's controversies. Academia can claim some credit for this, and academic institutions have continued to evolve in response to perceived problems, formalizing publication in journals, credit in citations, and evaluation in anonymous peer review.

Problems With Academia Yet little has really changed. Academia is still largely a medieval guild, with a few powerful elites, many slave-like apprentices, and members who hold a monopoly on the research patronage of princes and the teaching of their sons. Outsiders still complain about bias, saying their evidence is ignored, and many observers [Gh,Red,SmP,Syk,Tr,Tul] have noted some long-standing problems with the research component of academia.¹

As currently practiced² peer review is just another popularity contest, inducing familiar political games; savvy players criticize outsiders, praise insiders, follow the fashions insiders indicate, and

avoid subjects between or outside the familiar subjects. It can take surprisingly long for outright lying by insiders to be exposed [Red]. There are too few incentives to correct for cognitive [Kah] and social [My] biases, such as wishful thinking, overconfidence, anchoring [He], and preferring people with a background similar to your own.

Publication quantity is often the major measure of success, encouraging redundant publication of "smallest publishable units" by many co-authors. The need to have one's research appear original gives too little incentive to see if it has already been done elsewhere, as is often the case, and neglects efforts to integrate previous research. A preoccupation with "genius" and ideological wars over "true" scientific method [Gh] needlessly detract from just trying to be useful.

Perhaps the core problem is that academics are rewarded mainly for telling a good story, rather than for being right. (By "right" I include not only being literally correct, but also being on the right track, or enabling work on the right track.) Publications, grants, and tenure are based what other insiders think today, independent of whether one's ideas and results are proved correct or valuable later. Even for researchers with a good track record, grant proposals must usually describe in some detail exactly what will be discovered and how; true exploratory work is done on the sly. This emphasis on story-telling rewards the eloquent, who know how to persuade by ignoring evidence that goes against their view, and by other standard tricks [Cia].

¹Teaching reform is beyond the scope of this paper. However, I see no reason why my research reform proposal should make teaching worse.

²Early peer reviewers often personally observed experiments and tried to reproduce analyses.

Admittedly, someone who has published an unusual idea that has proven right is thought of more highly, all else being equal. But all else is usually not equal. Outsiders find it hard to get an unusual idea published, and being able to say "I told you so" is of little help to academics who have failed to gain tenure. The powerful often get credit for the successes of those under them [Re]. Only in the most experimental fields, where feedback is direct and frequent, can we expect people who are disliked -- but usually right -- to be rewarded through informal reputations.

Perhaps our biggest problem is the distortion evident when a science question becomes relevant for public policy, as in the recent debates over "Star Wars" or the greenhouse effect. The popular media tend to focus on those scientists prone to hyperbole. An honest consensus of relevant experts is often lost from public view, as advocates on each side accuse the other of bias and self-interest. Public policy can suffer dramatically as a result, a consequence that becomes more serious as the pace of technological change quickens.

On the whole, current academic institutions seem less than ideal, with incentives that reward being popular, fashionable, and eloquent, instead of being right.

Incentives Matter Are these complaints just sour grapes? Those who do well by an existing system tend to believe problems are minor. But even if the best ideas eventually win, we should worry if the people who advocate those ideas don't win. Good intentions and culture can only go so far in countering bad incentives; if you must publish or perish, you will do what it takes to publish (or perish).

The social organization of any human effort can have a tremendous effect on its efficiency. Consider that different past societies with different ways of organizing science have had very different rates of scientific progress; compare Europe with China over the last five centuries. Our rate of progress may be less than 2% of what it could be [Be].

Are we wasting precious resources? Imagine what would happen if we used academic peer review to decide what products to manufacture. Proposals for new products would be reviewed anonymously by powerful people who produce similar products. These reviewers would pass judgement without taking any personal

risk, and those judged favorably would win regardless of how useful their product turned out to be.

I much prefer our current business system, with all of its problems, where investors must take a personal risk when they endorse a product. Institutions like the stock market are comparatively egalitarian and flexible, allowing most anyone to participate in the ongoing debate about the profit potential of any public business or the relative potential of various industries, management styles, etc. Why can't we have academic research institutions more like this?

Academic Reforms Most efforts to improve academic institutions focus on incremental reform within the existing peer review framework. Should reviewers be anonymous? Should submissions be anonymous? How many people should review each proposal?

Occasionally someone proposes a more radical reform within the current framework. The surprising lack of agreement among reviewers [Cic] has lead some [Gi] to suggest we fund equally or randomly among "qualified" applicants, and let everything be published. Conversely, the fact that a small fraction of scientists receive most citations [Co] has lead some [By] to suggest that we simply give \$1M a year, no strings attached, to the top thousand scientists, chosen by an iterated popularity poll. Some have suggested universities and private labs be funded in proportion to their publication [Ro] or citation [Ts] count. And some [Tu] advocate prizes, once a central method for funding research [He]. Still others suggest scrapping the whole thing, abolishing tenure [SmP] or government funding [Fe,Wa] in favor of some existing alternative like private patrons, popular media, patents, or research tax credits.

Once in a while a whole new social institution is proposed. Science courts [Kan] (also called "scientific adversary procedures") were invented to blunt hyperbole on science controversies by using court-like proceedings to encourage cross-examination and to document areas of agreement. Hypertext publishing [Dr,Han88] imagines an electronic publishing medium where any critic could directly link a criticism to any published item, and where readers could decide what is worth reading by have software automatically combine the direct evaluations of previous readers they respect.

In this paper I propose a new academic institution, tentatively called "idea futures", intended to overcome some of the limitations of existing alternatives. It is utopian in the sense of describing a coherent vision of how things might be rather different, but hopefully practical in the sense of considering what could go wrong and how to start small.

What We Want Before considering specific mechanisms, let us reflect a moment on what we want from academic incentives. We want to encourage honesty and fair play; the game should be open to anyone to prove him/herself. Patrons who fund research, either private foundations or governments, presumably want research to be directed toward the academic subjects and questions of interest to those funders. (Patrons also include the researchers themselves, to the extent that reduced salaries are understood to be in exchange for some research autonomy.) On controversial questions, we want a clear measure of the current opinion of relevant experts, a measure which political advocates could not easily distort. And those who contribute to such a measure should have clear incentives to be careful and honest.

Presumably we want as much progress as possible per effort invested, at least in situations where the following notion of "progress" makes sense. Consider a well-posed question, such as "Is the Earth basically spherical?", with a handful of possible answers (such as "No, it's flat"). Experience indicates that, with enough study and evidence, one of the answers will eventually stand out as best to most anyone who considers the question carefully. At least this seems to happen for most questions that have been traditionally labeled "scientific"; questions about the morality of abortion or the nature of God may not fare as well. Where there is such a limiting "right" answer, "progress" can mean the rate at which general scientific opinion converges to that answer³.

Translating these goals to an individual level, we want our institutions to reward academics for pushing scientific opinion toward the "right" answer, presumably by somehow increasing their reputation, influence, or resources. Let

³This definition of progress is more objective than citation counts [Co], and hopefully avoids debates about whether more knowledge is good, or whether there is really an ultimate truth.

us imagine an academic who, after some reflection or observation, comes to a tentative conclusion which he/she would like others to consider. If most everyone already agrees with this conclusion, even without seeing the new supporting evidence or analysis, the academic should receive little credit for just making an "obvious" claim.

However, credit should be possible if the claim is surprising, i.e., if people who have not yet seen the evidence are not yet willing to agree. If, upon reviewing the evidence, most everyone now agrees with the surprising claim, then the academic should certainly receive some credit. And, in fact, peer review can handle this case. But what if there is not uniform agreement? It still seems that the academic should be rewarded, if this surprising claim is eventually born out. And others who supported this claim in the face of disagreement should also gain credit [Led], since they helped push the general opinion in the right direction.

Why shouldn't savvy academics now win credit by supporting as many claims as possible, or by multiplying controversies? Clearly they should risk losing credit when they are wrong, so that credit is in some ways conserved. The ratio of possible loss to gain should depend on how unusual one's position is. Siding with the majority and being right should gain one less than siding with a minority and being right. The total amount gained or lost should depend on how much of their reputation each academic has chosen to stake on this issue, as well as on how interesting the issue is to the ultimate research funders.

In summary, part of what we want from academic incentives is a fair game for staking our reputation, so that on questions of interest to funders, we converge as fast as possible to the "right" answer.

THE PROPOSAL

Surprising as it may seem, such a social institution exists. It is relatively simple, cheap, decentralized, and egalitarian. It could create a consensus on disputed science questions that would be clear, expert, honest, and self-consistent across a wide range of issues. This consensus should respond quickly to new information, and predict at least as well as any other co-existing consensus mechanism. It is well-grounded in our best theories of decision and incentives.

And it is ancient. We need only revive and embellish a suggestion made back during the utopian scientific revolution. Chemical physicians, excluded by the standard physicians from teaching in the British schools, repeatedly offered challenges like the following (circa 1651):

Oh ye Schooles. ... Let us take out of the hospitals, out of the Camps, or from elsewhere, 200, or 500 poor People, that have Fevers, Pleurisies, etc. Let us divide them into halves, let us cast lots, that one halfe of them may fall to my share, and the other to yours; ... we shall see how many Funerals both of us shall have: But let the reward of the contention or wager, be 300 Florens, deposited on both sides: Here your business is decided. [De]

They proposed to bet on their medical therapies, apparently believing bets to be a useful augmentation of the existing academic incentives! Bets are a long-established and robust reputation mechanism, widely seen as a cure for excessive verbal wrangling; you "put your money where your mouth is". In science and elsewhere, phrases like "you bet" are standard ways to express confidence. Offers to make token bets are particularly compelling, and scientists of equal stature often make and publicize such bets, with recent bets on resource depletion, computer chess, black holes [Hal], solar neutrinos, nuclear weapon yields [Ev], and cold fusion [Gar,Lew,WSJ].

Nor is gambling foreign to science funding. King Charles II, founding patron of the Royal Society of London, was fond of laying wagers on the outcome of the Society's experiments [ShS]. Until 1830, public lotteries funded Colombia, Harvard, and Yale [Gei]. In 1872 Leland Stanford, founder of Stanford University, hired Eadweard Muybridge to help win his bet that a trotting horse has all four legs off the ground at some point; in the process Eadweard invented moving pictures [Jac].

Consider the example of Piers Corbyn, a London astrophysicist who has been unable to get academic meteorologists interested in his unusual theory of long-term weather cycles [NS]. Since June 1988 he has been making bets to gain publicity, betting against the bookmaker William Hill, who uses odds posted by the British Meteorological Service. And he has been winning. Over

the last 26 months (4/89-5/91), Corbyn has made at least 9 bets a month (and averaged over 20 bets a month) and has won 80% of these bets, gaining an average rate of return of over 25% per bet. (Depending on what independence you assume between bets in a given month, the chance of this happening randomly is between one in 400 and one in 10^{50} .) Yet the Service still refuses to take Piers seriously, or make even token bets against him. Which doesn't seem quite fair; hasn't Pier earned the right to be considered? William Hill has taken on the bets for the publicity, but is tired of losing, and has adjusted their odds accordingly. Why shouldn't these be the odds used for official British agricultural policy, instead of the Service's predictions?

Or consider Julian Simon, a population and natural resource optimist, who found he could not compete for either popular or academic attention with best-selling doomsayers like Paul Ehrlich. So in 1980 Simon challenged Ehrlich to bet on whether the price of five basic metals, corrected for inflation, would rise or fall over the next decade. Ehrlich accepted, and Simon won, as would most anyone who bet that way in the last two centuries. This win brought Simon publicity [Ti], but mostly in the form of high-profile editorials saying "Yeah he won this one, but I challenge him to bet on a more meaningful indicator such as ..." In fact, however, not only won't Ehrlich bet again, though his predictions remain unchanged, but none of these editorial writers will actually put their money where their mouths are! And the papers that published these editorials won't publish letters from Simon accepting their challenges [Si]. Shouldn't Simon's open challenges count as much as best-sellers in setting environmental policy?

If the primary way that academics are now rewarded for being right, rather than popular, is an informal process for staking their reputation, which has various biases because of its informality, and if we want a better reputation game, why not literally make bets and formalize the process?

Imagine a betting pool or market on most disputed science questions, with the going odds available to the popular media, and treated socially as the current academic consensus. Imagine that academics are expected to "put up or shut up" and accompany claims with at least token bets, and that statistics are collected on how well people do. Imagine that fund-

ing agencies subsidize pools on questions of interest to them, and that research labs pay for much of their research with winnings from previous pools. And imagine that anyone could play, either to take a stand on an important issue, or to insure against technological risk.

This would be an "idea futures" market, which I offer as an alternative to existing academic social institutions. Somewhat like a corn futures market, where one can bet on the future price of corn, here one bets on the future settlement of a present scientific controversy. This is admittedly an unusual (though not entirely original [Bru, Ho81, Ho84, Lea, So]) suggestion; but consider what might happen.

SCENARIOS

Continental Drift In 1915 German meteorologist Alfred Wegener published his theory of continental drift, for which he had collected extensive evidence. But contemporaries considered his theory to be "impossible", and Wegener died an intellectual outcast in 1930 [Mar]. Yet in the 1960's his theory began to be taken seriously, and is now the established view. Wegener eventually gained fame, but overall academia seems to discourage activity like his. Some of Wegener's peers, for example, probably found his thesis plausible, but decided that to say so publicly would be a poor career move.

With idea futures, Wegener could have opened a market for people to bet on his theory, perhaps to be judged by some official body of geologists in a century. He could have then offered to bet a token amount at, say, 1-4 odds, in effect saying there was at least at 20% chance his claim would be vindicated. His opponents would have had to accept this estimate, and its implications about the importance of Wegener's research, or they would have to bet enough to drive the market odds down to something a little closer to "impossible". They could not suppress Wegener merely by silence or ridicule.

As Wegener increased his stake, buying more bets to move the price back up, his opponents would hopefully think just a little more carefully before betting even more to move the price back down. Others might find it in their interest to support Wegener; anyone who thought the consensus odds were wrong would expect to make money by betting, and would thereby move the consensus toward what they believe. Everyone would have a clear incentive to be careful and honest.

The market would encourage more research related to continental drift, as one could make money by being the first to trade on new relevant information. Eventually the evidence would more clearly tip in Wegener's favor, and the price of his bets would rise. Wegener, or his children, could then sell those bets and reap some rewards. While those rewards would not make up for years of neglect, at least he would get something.

As the controversy became settled, and opinions converged, people would gradually sell and leave the market. Few people, if any, need be left for the final judging, which could usually be avoided (using mechanisms to be described below).

Cold Fusion A more recent controversy began in March 1989, when Pons and Fleishman announced "fusion in a jar" at a dramatic press conference. In the months that followed, media aftershocks of confirmation attempts were tracked by thousands of scientists and others, who argued with each other about the chances of cold fusion being real. Proposals to bet came up often, even in the public debates. Critics, uncomfortable with airing scientific disputes in public, complained that Pons and Fleishman broke the rules by going to the popular media instead of through normal peer review channels, unfairly gaining extra attention and funding. Supporters countered that popular media spread information quickly to other scientists; cold fusion, if right, was too important to wait for normal channels.

In the journal *Science*, Robert Pool speculated that a market in cold fusion might have gone something like Figure 1 [Poo]. If there really had been a betting market, then there really would have been a market price that journalists like Pool could publish as news. A table of going prices might appear on the science page in the newspaper, much like the stock page in the business section, conveying current scientific opinion better than the current "balanced" interviews with extremists on all sides. It's been suggested [Ze] that the added information in betting market prices might have helped resolve the debate more quickly.

There needn't be a conflict between going through slow proper channels and getting the word out, if a fast market were a proper channel. The effect of staged media events might be reduced as it might not be news if the price didn't change; advocates would have to convince, not the average listener, but those people willing

to make bets. Remaining biases, such as the overconfidence evident in figure 1, would be reduced by technical traders and other trading specialists.

Cold fusion businesses would have been less risky to start. As it was, a new fusion business had to bet both that cold fusion was real, and that they were the best group to develop and market it in that case. With idea futures they could, by both starting a business and betting against cold fusion (essentially taking out insurance), really only be betting on their ability to develop cold fusion if it were real.

Insights from a great many people whose opinions on the cold fusion controversy were ignored, such as inarticulate folks without Ph.Ds, could have been integrated in a decentralized manner. Popular play would end up subsidizing professional efforts on questions of popular interest, offering more "direct democracy" in setting research priorities.

Neutrino Mass Betting markets could also function in the absence of overt controversy, as in the following (hypothetical) story.

Once upon a time the Great Science Foundation decided it would be a "good thing" to know the mass of the electron neutrino. Instead of trying to figure out who would be a good person to work on this, or what a good research strategy would be, they decided simply to subsidize betting markets on the neutrino mass. They spent millions.

Soon the market odds were about 5% that the mass was above 0.1eV, and Gung Ho Labs became intrigued by the profits to be made. They estimated that for about \$300K spent on two researchers over 3 years, they could make a high confidence measurement of whether the mass was above 0.1eV. So they went ahead with the project, and later got their result, which they kept very secret. While the market now estimated the chance of a mass over 0.1eV at 4%, their experiment said the chance was at most 0.1%.

So they quietly bought bets against a high mass, moving the price down to 2.5% in the process. They then revealed their results to the world, and tried their best to convince people that their experiment was solid. After a few months they mostly succeeded, and when the price had dropped to 0.7% they began to sell the bets they had made. They made \$500K off of the information they had created, which more than covered their expenses to get that information.

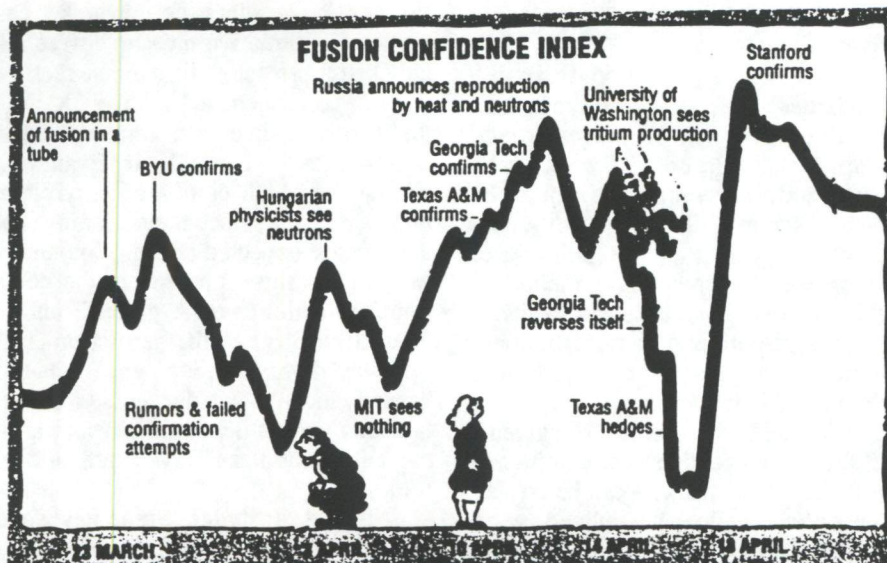


Figure 1 A Hypothetical Market in Cold Fusion

If Gung Ho Labs had failed to convince the world of their results, they would have faced the difficult choice of quitting at a loss, or holding out for the long-term. A careful internal review would probably be conducted before making such a decision.

Internally, Gung Ho would be free to use whatever organizational structures it found effective; even peer review, tenure, and fixed salaries. The two researchers need not risk their life savings to be paid for their efforts. But the discipline of the external market should keep these internal institutions from degenerating into mere popularity contests.

Killer Peanut Butter Once upon another time, Munchem Biolabs found compelling evidence that peanut butter was more deadly than most pesticides, a conclusion that Lunch Industries Exclusive (LIE) wanted desperately to suppress. LIE's usual procedure was to fund a bunch of competing studies to come to opposite conclusions, which usually kept the waters muddy enough that legislators and customers would ignore it all. But this time they had to deal with an idea futures market on the question, and the public was beginning to take the odds in such markets seriously.

Munchem had moved the market odds of deadly peanut butter up rather high. LIE now had two choices; either they could use overwhelming cash to move the odds back down, or use competing studies, advertising, etc. to persuade others to bet on their side.

If they bet alone, they would know they were throwing their money away with no obvious limit on future spend-

ing. Not only might Munchem find allies, but LIE employees who knew they were bluffing might be tempted to pick up a little free money with some anonymous bets. If word of Lunch's bluff got out, as insider information often does, investors would flock in and wipe out the effect of LIE's bets.

If LIE tried to throw away other people's money through a persuasion campaign, they would face a market dominated, as most liquid markets are, by battle-hardened speculators. These investors, not easily persuaded by clever jingles, would quickly hook up with research insiders, who generally know which labs tend to find whatever results their customers want.

So in the end, Lunch Industries accepted the market odds, and began research on non-toxic peanut butter.

PROCEDURES

Rather than just present an abstract utopian vision of market-based academic incentives, this paper aims to consider in some detail what problems might arise and possible approaches for dealing with them. The following is a core set of procedures tentatively selected to deal best with known problems, a core that will be expanded upon later in this paper. No doubt, experience with real idea futures markets will show many of these suggestions to have been naive. I offer them primarily to make plausible the idea that betting markets could be applied to a much wider range of scientific questions than is presently considered feasible.

(This section is somewhat dense, and may be profitably skimmed on a first reading.)

Assets Imagine that John bets Mary \$5, at even odds, that it will rain next Monday. Since they don't entirely trust each other, John and Mary put the bet in writing and each give \$5 to Frank, a trusted third party. John has essentially paid \$5 for an I.O.U. that says "Worth \$10 If Rain Monday", since if he wins he gets \$5 from Mary and his own \$5 back. Mary's I.O.U. says "Worth \$10 If Not Rain Monday". On Tuesday one of them can cash in their I.O.U. for \$10 from Frank.

This standard betting scenario can be improved by breaking it into different transactions; first create the I.O.U.s and then sell them. Replace Frank with a stable financial institution, let's call it a "bank", which will sell a pair of "\$10 if rain", "\$10 if not rain" coupons to anyone for a price of \$10. The bank takes no risk, since exactly one of the coupons will be worth \$10 in the end. And since the bank holds the \$10 in the meantime, it can afford to offer interest on the \$10, and perhaps pay a local meteorologist to be an impartial judge. Now Mary can first buy a coupon pair from the bank for \$10 and then offer to sell her "\$10 if rain" coupon to John or anyone for \$5, retaining the "\$10 if not rain" for herself.

A central clearinghouse for such offers, which matched compatible offers and insured that traders made good on their offers, would always hold a best current offer to sell and to buy. If the transaction costs of processing an offer through the clearinghouse were small, as current technology allows, then the "spread" between these offers could be quite small, leaving a going "market price". A going price of \$3.20 for "\$10 if rain Monday" would represent a temporary consensus of a 32% chance of rain Monday.

In general, these markets trade assets of the form "X if A" (often called "contingent assets"), where X is some pre-existing "base" asset and A is one of a set of mutually exclusive claims that some judging organization agrees, eventually, to choose from. The base X can be any stock, bond, currency, commodity, or even another compatible contingent asset. The set of claims constitutes a "question", and each claim is one possible answer to the question. To enable trading on a question, we require an agreement between several parties - an author, a judge, and one or more banks, registries, clearinghouses, and randomness checkers.

An author carefully words a set of claims, and a judging organization agrees if necessary, to offer a verdict in favor of one of these claims at some, perhaps indirectly specified, date. Registries hold records of public, i.e. not anonymous, trades made at clearinghouses. (Clearinghouses may be required to hold additional private records of all trades, available to be subpoenaed by criminal investigators.)

Consider a question with possible answers {A,B,...}. Any bank authorized in the agreement on that question can "split" any allowed base X (usually anything) into the assets {"X if A", "X if B", ...}, or "join" those assets back into X. In the example above, \$10 was split into "\$10 if rain" and "\$10 if not rain". The bank is trusted to report the net effect of these transactions to a central agent, who keeps track of the net "market capital" that has been split along this question.

On the specified date, and a short wait after a public announcement, the judges are given an agreed-upon judging-fee in order to study the question and render their verdict. Verdicts assign a percentage of validity to each of the possible question answers. If the verdict is 98% in favor of A, then banks are authorized to let people exchange their "X if A" assets for 98% of X.

The judging-fee is obtained from the banks, who devalue the current assets contingent on that question by some percentage, a percentage which can be no more than a pre-specified max-judging-percentage. This devaluation creates an incentive for traders to "settle out of court" and sell before the judging date.

What if there is too little capital in the market to support the required judging fee? John and Mary's market only has \$10 in it, and with a 10% max-judging-fee, only \$1 is available for judging, short of the \$5 a meteorologist judge might require. In this case we can hold an "audit lottery"⁴ [Pol]. The current market capital, \$10, is gambled with whomever offers the best price, among those approved by the randomness checker. If the gamble is won, every asset contingent on this question increases in value, resulting in enough market capital for judging to proceed, in this case \$50. If the gamble is lost, all such assets

become worthless and judging is not needed⁵.

Judges can be given more flexibility to deal better with uncertainties regarding when a question will be judgeable and how much that will cost. For example, the max-judging-percentage could be spent in discrete units, each with a specific percentage-unit and fee-unit. After spending each percentage-unit, the judges would have the choice to postpone judging to a later date and/or raise the next fee-unit. If necessary, an audit lottery would be held before each new unit.

If desired, judges can also be given a direct financial incentive to be careful and honest. "Appeals" markets can be created on the same question, but judged by an independent group much later and/or with a much higher judging-fee. For a limited period after a verdict is announced, an amount, up to a fixed fraction of the original judging-fee, would be spent trying to move the price in the appeals market toward the verdict specified. Judges would end up with some contingent assets saying their verdict would be upheld in the appeals market, assets they could sell immediately, at a loss, if they so chose.

Idea futures markets need no central management. Anyone could author a claim on any subject of interest to them, contract with different judging groups to judge that claim on different dates, and allow different banks to deal in each question. And anyone should be able to open a clearinghouse to sell any asset. All of these groups could compete openly for the attention and respect of investors.

Investors Investors could be as diverse as they are in current markets, each focusing on some specialty while avoiding risk from other areas. For example, if the market odds are "incoherent", i.e., deviate from the standard axioms of probability, a trader who corrects that deviation can make better than the average rate of return without significant risk. Therefore coherence specialists should keep the market consensus roughly consistent over a wide range of subjects. Similarly, technical traders would keep the pattern of price changes close to the ideal random walk [Mal]. The market odds should also quickly reflect information contained in any co-existing consensus measures, such as opinion polls or reports of elite com-

mittees, as traders could make easy money if alternative measures were reliably better predictors than the market.

A contingent asset, like "X if F", that is split again creates conjunctive contingent assets like "X if F and A". Conjuncts which combine many claims may be popular, since they offer investors the greatest expected return. Conjunctive assets also allow one to bet the conditional probability of A given F and remain insensitive to the verdict on F. In this way diverse traders, each of whom has only local knowledge, could manage a large network of dependencies such as the currently popular "Bayes net" models [Pe].

Social Attitudes Some new social attitudes toward these new markets are important elements of the envisioned approach. As with current financial markets, the market odds should be treated as the current social consensus on a question by popular media and policy makers. While one may of course disagree with this consensus in conversation, it is not impolite for others to inquire whether one who so disagrees has made investments commensurate with their wealth and the fuss they are making. People who do so invest should receive the same sort of social credit now granted to "do-gooder" advocates who devote personal resources to changing current opinion on some important issue. Like Phileas Fogg, the hero of Verne's *Around the World in Eighty Days*, "a man who rather laid wagers for honor's sake than for the stake proposed" [Ve], these investors should not be treated as mere risk-loving gamblers.

Social credit should also go to philanthropists who choose to subsidize a market on some important question. By funding an automatic inventory-based [St] market-maker, which always offers to buy or sell at prices determined solely by its current inventory, one gives away money only to those who move the market price in the direction of its final verdict.

Reputation scores could be computed from each person's public trades, recorded at registries. A trade is considered "public" if the trader committed at trading time to a date at which the trade would be publicly revealed, and that date has passed. One simple reputation score would be the ratio of the current market value of assets held to their value when purchased, corrected for a few distortions. People with high reputation scores should be respected for having been right against the crowd, and such scores might even

⁴This name is suggested by the way an auditor might randomly select expense reports for more careful scrutiny.

⁵Investors can insure against the added risk audit lotteries impose by putting money into a pot to be gambled in the same lottery, but on the other side.

compete with G.P.A.s or number of papers published as an evaluation measure.

OBJECTIONS

The main difference between "blue sky" fantasies and serious but radical suggestions is in how well they handle the details. If you are like most readers, you will by now have thought of one or more problems with or objections to idea futures. If so, you are encouraged to scan this section and go directly to the issues of concern to you. (Most of these issues have been raised by at least three independent commentators in previous discussions.)

Isn't Gambling Illegal? Yes, betting markets on science questions appear to be only legal in Great Britain, where they are highly regulated. Even Nevada, which allows sports betting, prohibits general betting to avoid scandals that might "taint" the gambling industry. Which is a shame because most of the arguments against betting, discussed below, do not apply well to science betting. We allow scattered markets that give us rather good consensus estimates on horse races and football teams, yet not on important science and technology questions! In the long term perhaps we can persuade legislators to allow science bets because of their extra benefits and reduced problems. Science betting certainly seems easier to justify than the currently popular regressive taxation through state lotteries.

Isn't Betting a Useless Zero-Sum Game? A standard argument for making betting illegal is to keep people from wasting their energies in unproductive activities. The only obvious value in betting on dice throws is entertainment, but laws to prohibit this usually also prohibit much more. Life insurance, joint stock companies [Bre], and commodity futures markets [Ros] were all prohibited by anti-gambling laws until advocates managed to obtain exemptions.

Being monetarily zero sum does not make betting useless. Betting markets allow traders to reduce risk, and create informative prices. In liquid markets most of the trading, liquidity, and price rationalization comes from speculators, for whom the market is basically a betting game. Buying any particular stock in the stock market, for example, is basically a bet in a zero-sum game when compared to investing in the standard "market" combination of all assets in the same tax and risk category. (While, if the prices are irrational, such bets may help the econ-

omy as a whole, this "externality" also benefits people not betting on that question.)

In fact, a standard way to analyze financial portfolios is to break them into contingent assets, each of which has value in only one possible world [ShW]. A "complete" market, where one can bet on anything, is best, allowing investors to minimize risk and maximize expected return [La].

Science bets would not only allow corporations to more easily insure against technological risk, but they would create prices embodying the sort of valuable information that governments now fund research to obtain. When the betting stakes are invested in stocks, the money is hopefully being put into productive use by those companies. Therefore, ignoring transaction costs and judging fees, the average rate of return of contingent assets split from stocks would be the same as the return on those stocks.

Does Anybody Ever Bet This Way?

Liquid markets in contingent assets are a somewhat different betting mechanism from the usual bookies or pari-mutuels. But they are not untried. Such markets are widely used to teach MBA students about how markets work [Fo], and are usually done on elections. Financial traders sometimes use them to bet on sports. And I have developed a board game where players use such a market to bet on a murder mystery as it unfolds. Most ordinary people learn the mechanism very quickly.

What About Compulsive Gambling? About 2% of the population seems unable to resist the temptation to risk more than they can afford to lose [APA] in casinos, racetracks, and high risk financial markets. Lost in the thrill of "action" and the hope that all of their financial worries will soon be over, they often regret their excess later, and resort to desperate measures, like theft, to pay debts.

Compulsive gambling is encouraged by advertising and easy access to games with a quick and possibly large payoff. British law reduces this problem by requiring casino players to apply 48 hours in advance, by allowing them to sign up on lists of people to be excluded from all casinos, and by forbidding youth and on-site alcohol, entertainment, and credit [Ke]. Margin limits in financial markets serve some similar functions.

Governments may impose similar rules to discourage compulsive gambling

in idea futures, though it is important that any advertising restrictions not prevent the wide dissemination of current consensus odds on important issues. More importantly, unless options (or investments on margin) are offered, science questions are generally too long term to be a problem, offering no more "action" than long-term stock investments. Traders who regret their purchase a few days later can sell and get most of their money back. And, given that many other options markets exist, it is not clear that allowing science options would increase opportunities for compulsive risky investing.

Is There Enough Interest In Science Questions? A recent science fiction [Bre] novel imagined wide-spread betting on science and technology questions, supplanting horse racing in popularity. And it is possible that having a direct, if small, influence and personal stake in science would heighten the public's interest. At present, though, fewer people probably follow science than football.

We don't need to interest everyone, however, just enough to pay for the modest overheads involved. Few people have interest and opinions about the future price of corn, yet corn futures markets thrive. A great many people are now involved in scientific research, many more follow scientific journals, and even more follow science in the popular media. Many of these people have strong opinions on various science controversies and feel they have insufficient opportunity to express them. Idea futures would thrive if it tapped only a small fraction of current interest and effort.

Having a fraction of science funding channeled through betting markets would certainly accomplish this. So might basic attitude changes toward seeing markets as a legitimate place to "take a stand" on important issues, trading scores as indicators of who is right more often, and the market price as a valid consensus measure. Idea futures does not need large sums of money to be successful; even when there is only \$100 bet on a question, the market still offers the social benefit of a visible consensus and incentives for honesty.

Will These Markets Be Too Thin?

In a market with low "liquidity", there are so few traders that you have to wait a while to find someone willing to trade with you. Automated market-makers [Hak], always ready to trade at prices determined by their current inventory, can

increase liquidity and maintain a small "spread" between their buy and sell price offers. And they can be very cheap if the basic transaction costs are low, which they could be if thousands of markets shared the same computerized market place.

But the market might remain "thin" in the sense that prices could change quickly against a trader in response to each small amount traded, so they would have to wait to get a "reasonable" price. A lack of expected market thickness can be a self-fulfilling prophecy, since traders prefer thick markets [Ec]. This is a standard explanation for the limited number of futures and options markets currently available.

Funding channeled through market-makers would of course thicken the markets, as would consistency arbitrage and conditional offers that connect questions. And improving computer technology, with lower transaction costs and automated trading strategies, should make thinner markets more tolerable. Besides, two people making a bet is a very thin market, but it happens all the time. And just one person posting an offer to bet on a new subject could be an important contribution to our social consensus.

Thin markets are known for being good places to find overlooked bargains, and are less prone to speculative bubbles (a single rational person can squash one). A thin idea futures market may actually seem better to some people, as the cost to change the current market consensus would be less. But thicker markets are better in general.

Doesn't Betting Only Work For Clear Cut Questions Like Horse Races?

Most organized betting focuses on questions which, like sporting events, will become very clearly resolved in a fixed time. This minimizes disputed verdicts and judging costs, and it makes sense for risk and entertainment-seeking bettors to focus on such subjects. But this does not imply that, given a specific subject area, betting markets are not a reasonable alternative to other consensus, reputation, and incentive mechanisms. Any incentive mechanism must pick some arbiter of quality, and subjects that are difficult for bets are also difficult for other approaches. For example, peer review, which uses averages of anonymous expert reviews as a quality measure, is widely believed to work better in the "hard sciences" than elsewhere.

Eventually most scientific controversies seem to get resolved enough to settle a bet. This resolvability is in fact central to popular notions of what defines science. Scientific claims are often defined as claims of "fact" which future evidence could possibly disprove [Pop], or at least alter our degree of confidence in. And science is widely believed to be "progressive", so that as evidence accumulates and relevant studies continue, opinions gradually converge. Beautiful theories killed by ugly facts are left behind. Or as Bacon said, "Truth is the daughter, not of authority, but of time".

Actually, most people believe that opinions on most questions of fact usually converge with time, evidence, and sincere study. We hope that history will prove us right. We debate and discuss, essentially saying "I'll bet if we talked it out, you'd see I'm right". We take the advice of experts, indicating that we think we would come to believe what the experts believe, if only we were to study what the experts have studied.

Even if we aren't sure whether opinions will converge, we think there is a good chance they would converge if only a knowledgeable and detached enough group would spend enough effort to study and debate the question. And if that group is diverse and independent enough, we believe we would probably agree with them. If so, we should accept their verdict to settle a bet.

How Often Do Beliefs Really Converge? Just because people believe their opinions converge, doesn't mean that they do. After all, there are strong social reasons to want to believe in convergence. Even if most questions that are settled today were once controversial, this doesn't mean that most old controversies are now settled. Perhaps yesterday's questions referred to concepts that are not even considered to make sense today. Historical studies, examining random scientific questions and claims of several centuries ago, should be done to shed light on these doubts.

But there are reasons to be optimistic. Standard decision theory, though it does not adequately account for the computational costs of deducing the implications of theories and evidence, is instructive and indicates that rational agents should come to agree [Se]. Consider an ideal decision theory agent who has a degree of belief in some particular claim A and continues to observe new evidence. Asymptotically, either all new evidence

will be irrelevant and have no bearing on A, or the agent will become certain about whether A is true or false. Now imagine that the claim A specifies a detailed possible world, i.e. says that the real world is one particular world out of the many possible worlds. If two ideal agents start out with wildly different beliefs, but neither of them is completely certain about A, and if they both observe the same not asymptotically-irrelevant evidence, then they will asymptotically come to agree about A.

Studies indicate that people also have strong tendencies to conform and agree when exposed to each others opinions [Li] and arguments [My]. In fact, the rate at which they come to agree often seems faster than can be rationally justified by decision theory. Randomly selected legal juries usually come to a unanimous verdict on complex legal questions.

What If Beliefs Never Converge?

Even if beliefs usually converged, idea futures might be unworkable if it dealt badly enough with situations where beliefs don't converge. One approach is to have mutually exclusive claim sets include a "this question too vague to judge" claim which the judges could choose if it seemed clear that no amount of study or time would ever allow a choice between the rest. Most people could then bet on the question conditional on it being resolved. This solution fails, however, if sincere beliefs never converge and yet it never becomes clear whether or not beliefs will converge. A deadline by which a question must be resolved could deal with this, but has other disadvantages.

If investors can reasonably estimate the chances that a question will be unresolvable in this manner, then the problem is manageable. High-risk questions will only be traded if there is enough disagreement [Jaf] or subsidies to justify it, and for low-risk questions the problem can be ignored. And, it seems, resolvability can be estimated. Questions about religion and morals are more difficult, as are certain long-standing riddles like the nature of consciousness. On the other hand, a question about a physical property of a substance, like a bond angle in some new molecule, seems quite resolvable. As a rule, one should prefer questions closer to direct observations. And general claims for which relevant evidence will always be available should do better than claims like what someone had for breakfast ten years ago.

What Do Convergent Beliefs Have To Do With Truth? The philosopher Peirce claimed that "The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by the truth" [Th]. However, the question of whether the convergent opinion we might all come to with unlimited evidence, study, and debate is the way the world "really" is, is beyond the scope of the paper. Even if it isn't "truth", we are all interested in it, and it's hard to think of a better truth-estimate on which to base academic incentives.

What About Badly Worded Claims? Even if an issue becomes settled, a poorly worded claim on that issue may be unresolvable. To avoid this, we need techniques for avoiding ambiguity and incentives for players to use them.

Wording a claim so it is both relevant to some important issue and minimally ambiguous is a skill that is routinely learned in many professions. Lawyers and philosophers obtain clarity through standardized words and language, and experimental scientists are adept at finding connections between abstract theories and specific observations. Claims should avoid slippery concepts and phrasing which allows many interpretations. Verbose annotations can also help by discussing motivations, examples, intended word meanings, judging criteria, etc.

If copyright laws are interpreted as applying to claim wordings, then claim authors may be able to charge an extra royalty fee for each join. Claim authors would then compete with each other for royalties from investors, who would prefer authors with reputations for writing clear and interesting claims. Added incentives come if authors bet against their claim being judged too vague.

To avoid excessive costs in forming a claim, a question could hold a "clarification lottery". After a certain time, or when the market capital reached a certain amount, judges could be funded in the usual manner to replace a hastily worded claim with a more considered one.

Even when one cannot really word a good claim to bet on directly, markets offer other ways to bet on a subject. For example, if one believed that when physicists disagree with chemists, the chemists are usually right, one could invest in a "basket" or mutual fund which bets on the side of chemists in as many controversies as possible.

Can't Wrong Ideas Still Be Useful? Absolutely. If you think an idea is prob-

ably wrong, but is probably more like the right answer than anything else around, then bet on that. If you just think that work on the idea is likely to inspire something interesting, then bet on that. These questions will be harder to judge though.

What If The Fine Print Differs From The Summary? Verbose claims would probably be described by short summary sentences or phrases in price lists, offers, etc. As with contracts and political ballot initiatives, there are problems when a deceptive title differs from the fine print. In extreme cases people might sue for misrepresentation, but usually we can only encourage the buyer to beware.

What About Sucker Bets? If a stranger offers to bet you on an oddball subject, there is a good chance they are trying to trick you with a deceptive claim. Even if it looks like you couldn't lose, you are well-advised to decline; the fact that they are making an offer gives you information.

In markets on pre-existing controversies where many traders have already examined the claims, this is less likely, though still possible. In general, traders should look claims over carefully and not bet unless they honestly think they know better than the other traders.

Don't Science Questions Resolve Too Slowly? The fundamental questions that get people interested in science, such as whether the universe is infinite, can take decades or even centuries to resolve. But this does not prevent markets in such questions. Most any newspaper will show that people regularly buy bonds scheduled to mature in forty years. Fifty year-olds who buy such bonds are not counting on living to be ninety; they know they can sell the bonds in the market at any time.

At present, you usually can't get a Ph.D. on whether the universe is infinite; you focus instead on a smaller question that is hopefully relevant for the bigger ones. Idea futures investors will similarly prefer shorter-term questions. A question that takes ten years to resolve (say starting at 50/50 and ending more than 90% certain 90% of the time) should have the same sort of daily price fluctuations (around 1.5%) as stocks do, and so support a similar mix of short-term speculators, and long-term fundamentals-oriented investors.

But for longer-term questions, investing in fundamentals is less attractive. Less information comes out per unit time

in a long-term market, so there is less money to be made for a given market thickness. And if you must hold out for decades until other investors come to their senses, the extra rate of return above the market average that you get for your information may be very small, and so you may prefer to quit now if you have better opportunities elsewhere. To make things worse, this creates an opportunity for strategic behavior. Someone might move the price in some direction and try to hold it there in the hope that other traders will not be willing to hold out as long and therefore quit at a loss.

Finally, you may not trust the underlying financial institutions to remain stable over a century or more. Few people would probably bet that "Nuclear war will destroy most of civilization", even though many people would like to for insurance reasons. And even if the banks don't go bankrupt, uncertainties about the relative long-term value of different base assets the betting stakes could be invested in may completely swamp any added return from winning a bet. This problem could be minimized if the "market asset" [ShW], a maximally diversified world mutual fund, became the standard base asset.

Even with all these problems, there will probably be rather thick and well subsidized markets on a few very basic science questions, as funding agencies and amateurs seeking to influence important issues would focus on them. Such questions could be connected, through a network of conditional offers, to related shorter-term questions which research could more directly resolve, allowing researchers of simpler questions to obtain some of the subsidies on the basic questions.

In financial markets, the conventional wisdom is that longer-term price movements are less rational, as there is less incentive to correct irrational deviations. But there is still some incentive, and so idea futures may still offer an improvement over the existing situation.

Why Should I Trust The Judges? Even when sincere opinions would converge, investors may worry about judges being biased by bribes or various shared interests and associations. Fortunately, investors get to pick the assets they buy, and therefore the judges they bet on. So they can prefer long-lived judging organizations with reputations for fairness and avoiding scandals, and which use various available means to discourage foul play.

Incentives for traders to settle out of court and avoid judging altogether certainly help avoid judging foul play. So do clear-cut claims and judging criteria that leave little room for judging discretion. If we wait so long that the right verdict becomes "obvious" it would also be hard for judges to cheat. Also more trustworthy are juries of people who have never had a stake in the question, randomly selected from a large population, deliberating openly and offering to consider any relevant evidence.

The question of whether some proposed evidence is relevant for some deliberation could even have its own betting market; juries could offer to consider any evidence for which the market odds of relevance were above some threshold.

Incentives to detect foul play could come from both the ability to sue cheating judges, and possibly from large bonds which judges might post payable to anyone who uncovers such corruption. Also, any persistent difference in the market odds on the same claim with different judges would constitute consensus about judging bias, flagging those judges for closer scrutiny. Judge rating agencies might form. Finally, "appeals" markets can give judges a direct incentive to be careful and honest, since judges must then bet that their verdict will be upheld on appeal.

Won't Judging Cost Too Much?

Through audit lotteries, one can keep the percentage taken by judges below any given threshold, and still afford to pay for very detailed judging, even going so far as to choose many jurors from widely different cultures and train them in one or more specialties before having them adjudicate some specific issue! This approach is mainly limited by risk aversion, which limits the attractiveness of large wins. Most people will not want to bet so much on any one question that the amount they might win would be much more than their total wealth. A one in a billion chance of winning a billion dollars is not worth as much to most people as a one in a thousand chance of winning a thousand dollars. If the amount one would need to bet to avoid this effect is too small, it is not worth the bother and people will bet nothing on the question.

Won't Wealthy People Have Too Much Influence? Markets are not opinion polls where the rich get more votes; to use market influence one must risk losing it. As in existing financial markets, rich investors who are not special-

ists in some particular area will prefer to get investment advice from someone who is a specialist, or avoid investing in that area entirely. This is similar to the way that powerful people defer to academic specialists now. Rich people who carelessly throw their weight around will lose their riches.

Even so, the wealthier social classes will have more influence, as they do now in most areas of life, including academia. If this is a problem which you are willing to invoke the force of government to solve (I am reluctant to do so), then the natural solution is general wealth redistribution. This is much more cost-effective than crudely trying to keep the rich out of any particular walk of life.

If you worry that markets would create large inequalities in academia, don't. Influence in academia, as measured for example by number of papers published [Pr], is far more concentrated than in most walks of life. It seems unlikely that markets would make things worse, and could well make things much better, as people would not need degrees or the blessing of the academic elites to play as equals.

Won't The Market Be Dominated

By Fools? Again, markets are not opinion polls. Anyone *can* invest in any open market, but they only choose to invest where they think they have special insight or insurance needs. Even if they are mistaken about their special insights into, say, the gold market, they are fairly quickly taught otherwise. Most people who play commodity markets, for example, lose their stake and quit within a year. Such markets are dominated by the minority who have managed to play and not go broke. If you believe otherwise, and know of some market where the prices are obviously wrong, I challenge you to "put your money where your mouth is" and take some of that free money you believe is there for the taking. It's easy to bad-mouth the stupid public before you have tried to beat them.

Won't Advertising Manipulate

Opinion? Advertising, in the sense of campaigns to persuade through evidence and arguments, exists now in academia and would certainly persist. Advertising, in the sense of clever jingles and sex appeal to grab the subconscious of the impulse buyer, should not be a problem. People do not try to affect the price of corn futures with clever jingles; it would be like trying to sell cars by offering free balloons to Consumer Reports techni-

cians. The savvy investors who dominate markets are smarter than that.

Aren't Markets Full of Cheats and Thieves? Yes, but this does not usually distort the incentives or the consensus price much. Most cheating is not "manipulating the price", which is rather hard to do in a liquid market, but conflicts of interest where people who supposedly represent others instead act in their own interest, giving poor advice to clients and using information gained from clients.

Insider trading is mentioned below. But brokers and investment advisors are the worst case. In markets you win whenever you can get others to do what you just did, or when you predict what they will do and do it first. Brokers and investment advisors often tell you to buy whatever they would like to sell, and charge you large commissions for the "advice". Brokers often trade for themselves just before they execute trades for you; stop orders and margin calls are especially lucrative.

To avoid being cheated, be careful who you trust. Avoid brokers who trade for themselves, and advisors who do not take the same risk they advise for you.

As bets, idea futures markets cannot be cornered or monopolized. No matter how many bets have been made, other people are always free to bet more.

What About Insider Trading? When an employee of a company makes money by trading on inside information they have about that company, or by telling someone else so they can trade, that employee is considered to be going against the interest of the other stockholders who own the company. Employment contracts and laws can forbid this conflict of interest, though price movements just before major announcements show that a substantial amount of such trading happens anyway.

Fortunately nature has no insiders or employees. The only similar problem in idea futures is when a research lab is trying to keep a result temporarily secret before trading on it, and an employee sneaks out and trades first. This could be dealt with exactly as stock insider trading is now, through private trading records accessible to criminal investigators.

What About "Moral Hazard"? One of the advantages of a market is that it offers incentives to anyone to come and contribute their knowledge about the world. A disadvantage is that, since changing the world can give one special knowledge about it, people may have an

incentive to cause harm. If we allow anyone to bet on your lifespan, then someone may decide to kill you just to win a bet. And this murder may be much harder to solve than most since, with anonymous trading, most anyone might be a potential suspect. (Though criminal investigators may be able to learn who really made what "anonymous" trades.) For this reason, there are usually restrictions on who may buy how much life insurance on you.

Moral hazard should be less of a problem for basic questions about nature that people cannot change, though it could conceivably be a problem for short-term trading and options that bet on when information will come out. We wouldn't want someone to blow up the latest accelerator to prevent results from coming out, or to kill some patients to slant a medical study.

Yet we shouldn't prevent open markets if the chance of foul play seems small. Anyone is allowed to trade stock, even though there is a possibility that someone will sell short the stock of the makers of a pain reliever, and then poison some packages to depress their sales. Only for the rare claim where the risk of harm seemed particularly high might one justify a prior restraint limiting who could have how much stake on the different sides of a question.

What About Incentives To Start False Rumors? A "rumor" is just information, perhaps false, passed informally through a social network. Maliciously false rumors occur whenever people both have an interest in what other socially connected people think about a question, and when there is inadequate feedback for learning what rumors were false, so that people can discount unreliable sources.

In current academia, there is often enough feedback to discourage false rumors about what results are about to be published. Word of mouth which discredits a junior researcher, however, can trash his or her reputation without others ever really finding out if the rumors were right.

Markets both encourage and discourage false rumors. Markets give more people an interest in fooling other people, but also improve the feedback about what rumors were right. And the market price offers an alternative to informal information channels. Again, don't believe everything you hear; trust advisors with a good track record who take the same risk they advise you to.

What About Incentives To Keep Information Secret? If you acquired a piece of information where it was clear which side of what questions the information favored, then your best strategy would be to buy on those favored sides, reveal and publicize your information (perhaps after selling it to other traders), wait for the price to rise, and then sell at a profit. If, however, the implications of the information are not clear, you might be tempted to sit tight and wait for further revelations, even though you risk other people stumbling on to your insight in the meantime. It is similar with incentives to publish. Unless you can connect your insight to currently popular issues, and package enough of them together to make a paper, you cannot get published and so you may keep the idea to yourself.

One approach might be to formulate a question more closely related to your information, and then try to convince some funding agency that your question is interesting, even if its implications are not clear. Or you could subsidize your question, in the hope that this would encourage others to figure out its implications and create conditional offers connecting it to other questions. Either approach might induce enough market thickness to make your information pay off.

Won't An Apparent Consensus Create A Crowd Mentality? People might think they agreed more than they actually did, defer to a consensus that had little thought behind it, and so create the social analogues of anchoring and overconfidence [Kah]. Would creativity be suppressed?

Markets with less thought behind them should give themselves away by being thinner. If not, and some of us catch wind of this trend, we could make money by correcting for it. And, for what it's worth, the market odds at horse races actually tend to be underconfident, being biased toward long-shots. Markets encourage people to be contrarian; the only reason to trade, to not own the same mix of investments as everyone else, is because you think the consensus is wrong, or for insurance needs.

Will The New Incentives Slow or Stop Convergence? This is the opposite of the above problem. People with a stake on a certain side may become mentally biased toward that side, resisting the rational implications of mounting evidence. This is of course not a new phenomenon in academia, and so it's hard to see why the problem would be worse.

Except for issues closely connected to basic "ideologies" about which most everyone has an opinion, we can hope to find impartial jurors not overwhelmingly biased by either side.

Won't Different Claim Wordings, Judges, And Base Assets Confuse The Consensus? Unless the performance of a base asset correlates with a claim, the claim's market odds should be independent of base, and arbitrageurs can easily enforce this. If the prices on the same claim judged by different judges were persistently different, this would constitute consensus about judging bias, a situation that judges would want to avoid. If different claim wordings on an issue have very different prices, this represents consensus that there are really several different issues to be distinguished. For each distinguishable issue, traders seeking liquidity will probably congregate around one or a handful of base asset/wording/judge combinations, thereby avoiding a combinatorial explosion.

Won't The Consensus Reflect Risk Preferences As Well As Beliefs? Yes, the amount one should bet depends on one's beliefs, attitude toward risk, and the stake one already has in a question [Kad]. Risk-avoiders bet less than risk-takers, and bet less on the side that they already have a stake in. Price distortions from this should be minor, unless most everyone has substantial non-betting stakes on the same side, or if beliefs correlate significantly with such stakes, and if the stakes held approach each person's total wealth. One exception is that few people would bet for "Technology will soon make us all too rich to care about money", even if they believed it.

It might seem that questions with extremely lop-sided odds would also be a problem. Too few people might bet that "energy is conserved" (EC) if they very confidently expecting to win very little. But by splitting EC assets along other questions, people could jointly support EC, debate other questions, and get a higher average return. In general, traders should keep splitting until liquidity or risk considerations dominate.

Some people have worried that opinionated yet extremely risk averse people, unwilling to bet on anything, would be unfairly labeled "insincere" debaters. But it is hard for me to imagine that they could not afford to risk even \$10 a year so that we could develop a reputation score for them. If it is the risk of a low reputation score that scares them,

perhaps they should not act so opinionated.

Won't Betting Challenges Discourage Creativity? If people were expected to bet on every idea that comes out of their mouth, they would be more reluctant to think up wild ideas, most of which are going to be bad. Hopefully we can maintain a distinction between saying "Here is an interesting idea to think about" and "This is the way it is, why won't you agree?", only expecting people to put up or shut up in the second case.

What's The Point of a "Consensus" That People Disagree With? Regardless of the name used, people often want to pool their differing individual estimates on some issue into a composite estimate. This is most clearly needed in the "public choice" problem, where citizen estimates must be combined into government policy. But we also have a more general need for social institutions where experts combine their estimates on some subject into composite estimates, estimates that non-experts can use to make individual choices. Several such institutions may compete for attention, but the need remains.

Most work on consensus measures [Gen,Gr,Syn] focuses on various explicit functions for combining individual beliefs, and some simple variations of these [Man] are now used as academic consensus mechanisms. Compared to these, betting markets not only offer superior incentives [Ei] for people to bother to make their beliefs explicit and honest, but betting markets have the following unique claim to the word "consensus".

It is in the personal interest of an ideal decision theory agent to make all external actions as if they agreed with the market consensus [Kad,Na], without any coercion. Agents should buy contingent assets up to the point where their marginal rates of substitution are the same, i.e. where they all agree on the relative value of getting one more dollar for sure vs. even more dollars in some contingency. An external observer, who can offer agents trades or choices but cannot tell how much each agent has already bet, cannot tell that the agents internally disagree.

Insurance-based proposals [Fa] are similar in spirit to the betting markets proposed here, as is the following proposal for dealing with the public choice problem [Mu]. If a government threatens to make a change, sells insurance on the change either way, and then makes the

choice that is cheapest for them, they produce an efficient "Pareto optimal" result.

Isn't It Better For People To Argue Out Their Own Disputes? Yes, which is why we want incentives, such as audit lotteries, for parties to settle out of court and avoid judging. Idea futures is only intended to discourage insincere debaters.

Another way to avoid judging is to hold "argue lotteries" which are like audit lotteries except that judges are not invoked. The idea is to focus attention on a smaller number of markets where more is at stake. This should induce more discussion and examination of such questions, perhaps resulting in more related questions being formed. Hopefully, opinions would naturally converge, and people would leave the market. Judges are really only there to discourage self-deception and strategic bargaining, so that the market odds eventually reflect the "obvious".

Won't This Have The Same Problems As Patents? No [Hir]. With patents we must decide who owns an idea, and so a centralized legal system must make a great many subtle decisions with insufficient evidence and expertise. We must examine history to decide who contributed how much to the idea. We must define some sharp legal boundaries that determine what it is to use the idea. With present patent law, we must also decide if an idea is true, if it is "original", if it is "obvious", if it is a "process", if it was revealed properly, etc. Bets are much more flexible; we need only decide if an idea is right, and we can each choose who is to judge that question. Government intervention and international agreement are not needed.

Wouldn't Anonymous Trading Screw Up Reputation Statistics? Perhaps people could make private trades to move prices out of line, and then make public trades on the other side to bring them back, so that those trades do better than average. This is somewhat like giving someone a wad of money by dropping it in the park and having them wander by an hour later to pick it up. If the park is crowded enough, someone else will have found it by then. In the market, anyone else could make money by stopping the price from moving out of line. The problem is more serious, however, if everyone accepts that only one trader has any information about a question, and so no one else wants to bet there. If identifiable, such markets should be excluded from reputation scores.

If This Is So Great, Why Hasn't It Happened Already? If it was in people's interest, wouldn't there be such markets by now? Well, if we always assumed this we might never do anything new, but it's important to ask this question. The fact that science bets have been legal only in Britain, and then only in the last three decades is only part of an explanation.

English bookmakers perceive little demand for science bets, and so take them mainly to induce popular articles mentioning the going odds on unusual subjects [ShG]. This publicity brings in new clients, who may then be switched to the "real" betting on sports. Because of this, bookies prefer small bets on subjects "in good taste" that anyone can understand, like UFOs, Yetis, and Moon landings. They avoid subjects that seem too esoteric for the general public, like the recent "cold fusion" claims, and subjects that won't very clearly resolve themselves, as a judging industry has not yet evolved.

Bookmakers traditionally prefer to set prices and stick to them, rather than setting up markets in order to play market-maker with the fluctuating prices. Because of this, they are usually unwilling to offer bets on claims where they do not know how to estimate the odds, and few bookies have advanced science educations. As a result, they mainly take safe bets, siding with the scientific establishment against "crazy" outside theories, which doesn't help the image problem betting has in many quarters.

English bookmakers do not seem to have seriously tried to sell imagine-conscious academics on science bets, through arguments like those in this paper. Nor, to my knowledge, has the possibility for betting markets as a funding mechanism been pointed out. Questions of interest to academics are now avoided and no visible influenceable consensus is formed; one cannot even subscribe to a publication listing the going prices on science questions. It should be possible to improve on this.

Can Nations Funding Research This Way Appropriate the Benefits? A popular argument for government-funded research says that, left to themselves, people won't produce enough basic knowledge. If a knowledge producer publishes its results, then "free riders" can use this knowledge without paying the producer [Pa]. Patents on basic knowledge are considered too fuzzy to enforce, and trade secrets are said to fail because of difficul-

ties keeping basic information secret, and in figuring out who would find basic knowledge useful.

Of course if nations do subsidize research, they can fall victim to international free riders, i.e., countries that mainly apply research done elsewhere. Some discount this by saying that most research knowledge is never published, but tacit and embodied in the skills of the researchers. Thus subsidies largely benefit researchers and companies located near enough to easily collaborate with and hire such researchers. Of course such a locality of benefits would suggest that research is best funded at a local level, or even privately within a large university campus.

A need for local appropriation of benefit argues against indirect funding methods, like prizes or idea futures, which cannot as easily control where the research they induce is performed. But such mechanisms might be well suited for science-for-its-own-sake philanthropy and for international funding of research, as such indirect methods can better avoid favoritism toward any particular nation.

Shouldn't we appeal to higher motives than greed? The very formulation of the patron's problem, how to best promote scientific progress given a fixed pile of money, forces one to deal with money. Money is what the patron has to offer. So the patron can only influence people that care to some degree about money, or that care about something else controlled by people who care about money.

STRATEGY

It's a lot easier to sketch a grand utopian vision than it is to figure out how to get there from here. An ideal development strategy would show how to grow incrementally, with each self-supporting step leading naturally to the next one. Most utopian visions fail because they, instead, require too many things to change all at once.

One advantage of idea futures is that, if not legally prohibited or socially shunned, it can co-exist with existing academic institutions and incrementally attract investors, patrons, and controversies. Papers would still be published and elite committees would still convene. Professors would gradually make more side bets, and begin to challenge each other to bets. Journalists would gradually rely more on the market odds for news stories, and funding agencies would gradually try larger levels of subsidies. Idea

futures could rise or fall on its own merits, as people studied how well its predictions compared to other consensus measures, and how the rate of progress in a field depends on the fraction of funding channeled through the markets.

Unfortunately, there seem to be some obstacles to overcome before gradual growth is possible. Economies of scale in forming reputable judging organizations or building secure computerized marketplaces may mean that certain levels of participation may be required before idea futures can "take off". But the major hurdle seems to be attitudes toward the very idea, attitudes reflected in the worldwide legal prohibitions. There are several possible strategies here.

One approach is more discussions, like those in this paper, of the need for alternative academic institutions, and of betting markets as a particular alternative. Perhaps we need simple word tricks, like insurance and stock bets have used, to disassociate idea futures from ordinary betting, though the concept of bets is very useful in explaining how it works.

Also helpful is further research on markets in conditional assets, such as recent attempts to show them superior to opinion polls at predicting elections [Fo]. Laboratory experiments [SmV] comparing betting markets to some mockup of existing peer review institutions would be very interesting, though not of course decisive.

A different approach, which I am also pursuing, would be to create an electronic mail-based reputation game, where people play for "bragging rights" instead of money. This would avoid legal problems and the discomfort academics have in dealing explicitly with money, and would allow many people from around the world to participate in a less-threatening partial test of markets as an academic consensus mechanism. However, avoiding money makes the incentives suspect, and precludes many of the advantages, like insurance, that idea futures offer. In particular, it makes it hard to pay judges enough to do a careful job. If enough people played, the scores would mean something to observers, and so people might have an incentive to play and play well. But building a game up to this status would be hard, probably requiring some "big name" players to attract others.

If the basic idea became plausible enough to enough private patrons in Britain (because that's where it's legal) or government patrons anywhere, idea fu-

tures could be seriously tried. The initial field would preferably be one where bets are easier to settle, like number theory, though such subjects tend to be ones where existing institutions also work better, and so perceive less of a need for change. A socially important question with minimal opportunities for conflict of interest would also be nice. Attractive initial candidate fields include number theory, meteorology, remote sensing, and particle properties.

Idea futures will have "made it" when it becomes known as a good place to find out the latest thinking on certain issues, reliably predicting what will later become consensus in other social contexts.

ADVANTAGES

If its potential problems can be overcome, and a development path charted and followed, idea futures offers many advantages, most of which have already been mentioned.

There would be a clear incentive to be careful, honest, and expert when making public statements. Opinion holders could be rewarded for being right, rather than just for being liked by academic insiders. Those who invest wisely would accumulate capital and gain influence, which they could reinvest in discretionary research or in influencing future consensus.

Funding agencies would only need to pick important questions, not who would be good to research them, what methods ought to be used, nor when the research should be done. Diverse approaches could be tried to research a question, without arbitrary penalties against crossing disciplinary boundaries, ignoring fashion and insiders, integrating pre-existing knowledge, violating methodological ideologies, or using insights too small or inarticulate to make a publishable unit. Any approach by which one could reliably make the consensus odds better informed could be financially rewarded.

Anyone, not just articulate Ph.D.s, could contribute directly to the world's corpus of knowledge. Easily published science odds and amateur betting should increase popular interest in science. And even if the "great unwashed" turn out to be poor contributors, they would subsidize professional efforts on questions of popular interest, and perhaps increase the general savings rate. And I suspect they will do better than most elites expect.

Clear market odds would ease science reporting. A visible scientific consensus would be available to guide public policy, a consensus which would be self-consistent across a wide range of issues and harder for media campaigns to distort. Compared to competing consensus mechanisms, idea futures should be relatively simple, cheap, decentralized, egalitarian, responsive to new information, and at least as informative. This consensus should correct for many current biases, such as overconfidence.

The mere threat of betting challenges could improve incentives in discussions and debates. If the market consensus carried social weight, it could serve as a coordination point for thousand of independent conversations. A rejected visionary would have a new way to get publicity for his ideas, and a reward for being right against the establishment; true cranks would subsidize leveler heads. As debates became settled, they would leave a trail of agreed-upon statements which could be used to counter bogus claims made by those ignorant of solid expert consensus.

Businesses could make insurance hedges against technological risk, as in the cold fusion case. While such insurance may be legal now, the introduction of speculators would increase market thickness to a point where it might be practical.

Reputation scores offer a new way to evaluate people's ability to separate the wheat from the chaff in ideas and arguments, and these scores should depend less on whether one has curried favor from the right people.

Idea futures is well-grounded in our best theories of decision and incentives. Once legal and accepted, idea futures could grow incrementally, and perhaps dramatically increase our rate of scientific progress per funding spent.

CONCLUSION

Markets in contingent assets, more commonly known as "bets", offer a needed alternative to existing academic institutions. Betting markets cannot solve all current problems, or replace all current institutions. But if this paper has been successful, the potential of such markets should be clear, and most of the obvious problems with such markets should have been addressed in enough detail that we can say the idea still seems plausible on a closer examination. If so, more serious intellectual discussion is justified, and

perhaps some small-scale experiments. We could do much worse than having intellectual institutions as open, flexible, diverse, and egalitarian as the stock market, with incentives as well-grounded and with estimates on important issues as unbiased and predictive.

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"Document Control"

TYPE: ACTION DOCUMENT NUMBER: 9202260
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: HOCHHAUS, Larry: OKLAHOMA STATE UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/31/92

SUBJECT: HE IS FORWARDING COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

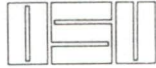
ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/20/92 STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

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OSTP RECEIVED: 08/06/92 DEPT RECEIVED:
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Oklahoma State University

DEPARTMENT OF PSYCHOLOGY

July 31, 1992

2260
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STILLWATER, OKLAHOMA 74078

(405) 624-6027 92 AUG 6 P2:15

7STP
MAIL ROOM

D. Allan Bromley, Ph. D.
The Assistant to the President
for Science and Technology
President's Council of Advisors
on Science and Technology (PCAST)
The White House
Washington, D. C.

Dear Dr. Bromley:

A memo from my University president indicates you seek commentary pertinent to the role of institutes of higher education in providing scientific and technical talent and in providing a steady flow of new knowledge and ideas. I am happy to help.

The view I would like to emphasize asserts the need for basic research. Over the last 20 years I have seen a steady diminution of governmental interest in knowledge for knowledge's sake. I believe this has been a mistake.

Some would say the multi-billion dollar proposed super-collider is such a project, yet I would oppose this project in favor of ways to more effectively stimulate basic research and to do so more broadly.

Imagine what a \$5,000,000,000 investment in social science at the level of basic, not applied research could do to relieve human suffering and human problems. Cynically, I feel the reason we are willing to fund the super-collider is a) its value as a pork-barrell project and b) its potential to provide high technology applications to technical problems.

I guess I've made the point I wanted. I would like to see more investment in basic research, but would also like to see a shift from research in physical sciences to the area of social sciences. It is time my nation dropped its "bottom-line" attitude toward every situation and began investing in things to help people not for profit, but because it is the right thing to do.

I appreciate the invitation to write to you.

Sincerely,

Larry Hochhaus
Professor

TYPE: ACTION
ORIGINATOR: 02

STATUS I

DOCUMENT NUMBER: 9202178
DIRECTORATE STATUS

FROM: HANSON, Robin: NASA AMES RESEARCH CENTER

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/31/92

SUBJECT: HE IS FORWARDING COMMENTS FOR THE PCAST PANEL
STUDYING THE HEALTH OF U.S. UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/17/92 STAFF DUE DATE
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COPIES TO: D. Allan Bromley

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2178

July 31, 1992

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President's Council of Advisors on Science and Technology, and
D. Allan Bromley, Assistant to the President for Science and Technology
Office of Science and Technology Policy,
744 Jackson Place, NW., Washington DC 20506

OSTP
MAIL ROOM

Dear Dr. Bromley and other P.C.A.S.T. members,

I applaud your current efforts to "seek input from many sources" on how to "retune" institutional roles and relationships ... between the Nation's research-intensive universities and the Federal government". Indeed "much has changed" since "that relationship was forged a half century ago", and a more fundamental review is perhaps overdue.

Current storms will probably blow over, and cosmetic changes may suffice to preserve business-as-usual for up to another half century. Even so, I urge you to spend some fraction of your time considering the possibility of more radical change. The winds of change often come suddenly, and with gale force, rewarding those who considered their options when the wind was light. A more fundamental review of the relationship between citizens and those they pay to do basic research must reconsider, not just the average grant size or the number of reviewers, but the basic idea of proposal peer review.

The most basic institutional issue, in science and elsewhere, is *accountability*. U.S. taxpayers are the ultimate funders and beneficiaries of federally-funded research. Researchers, research administrators, and federal oversight agencies are supposed to act as "agents", being paid to seek what is in the best interest of their taxpayer clients. As in most walks of life, clients are concerned that these agents will act in their own best interest, instead of that of the clients. To encourage agents to be accountable to their clients, contracts and institutions are formed, structuring the communication and rewards of their participants.

Yet federal proposal peer-review of research is not a particularly accountable institution. To whom do the researchers account, once they have been awarded funding? To whom do the peers who review account, so that they are discouraged from indulging old-boy networks and other conflicts of interest? To whom do the federal administrators account for their bets on which fields are most promising? Yes, the voters could reject the party in power, if their life is not as full as expected twenty years later, but this feedback is terribly weak.

Now managing basic research is notoriously difficult, so one might be excused for suspecting that nothing better is possible. But in fact science has been funded

through a rather wide variety of institutions down the centuries and around the world, many of which seem substantially more accountable than proposal peer-review. Let us draw on this history, on models from related areas of human endeavor, and on our growing understanding of institutional theory and the research process, to explore alternative ways we might fund research.

One particularly robust strategy for structuring state institutions, is *privatization*. Private organizations compete to gain rewards based on well-defined performance criteria. For example, if a city council can define what it wants in terms of local trash collection, this task can be assigned to the lowest-bidder who agrees to follow this definition. In this case, the client need only notice whether the trash is being collected as defined, and can ignore most other aspects of its agent's behavior.

One way to privatize science funding is *prizes*, and in fact prizes were a dominant science funding mechanism from one to three centuries ago. If we want a human genome sequenced, we just offer a prize of so many cents a base-pair, awarded to any private party which first sequences, and publishes, any part of the genome. Prizes work well for any specific achievement which you can foresee wanting to have happen, and for which one can easily determine who was responsible.

But often what you know you want is to eventually get an answer to a certain question, such as the age of the universe, even if you can't foresee what specific achievements will contribute to it. In this case, you might subsidize a *betting market* on that question. Private research groups would then compete to predict which answer to the question will eventually become widely accepted. Of course this approach hasn't been tried much, and is currently illegal in the United States. A paper of mine on the subject is enclosed.

Are such radical alternatives to current institutions really feasible? We won't know unless we try them somewhere and compare. And we should try; getting more research bang for our buck would not only please the patrons, but increase demand for the research product.

Sincerely yours,

Robin Hanson
MS 269-2, NASA Ames Research Center
Moffett Field, CA 94035
W: 415-604-3361 H: 415-651-7483
hanson@charon.arc.nasa.gov



National Aeronautics and
Space Administration

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D. Allan Bromley + P.C.A.S.T.
Office of Science + Technology Policy
FAX: 202-395-5076

APPROVED _____

DATE _____

Signature - Branch Chief or Higher

"Document Control"

TYPE: ACTION DOCUMENT NUMBER: 9202262
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: HYTCHE, William P.: UNIVERSITY OF MARYLAND

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/30/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/20/92 STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

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REMARKS: *ARN per AKD* PHONE: EXT:

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UNIVERSITY OF MARYLAND EASTERN SHORE

OFFICE OF THE PRESIDENT

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PRINCESS ANNE, MARYLAND 21853-1299

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02 AUG 6 PM 2:48

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CAMPUS: (301) 651-2200
FAX: (301) 651-2270

July 30, 1992

Dr. D. Allan Bromley
Assistant to the President for
Science and Technology and
Director of the Office of Science
and Technology Policy
Executive Office of the President
The White House
Washington, D.C. 20500

Dear Dr. Bromley:

We appreciate the opportunity to provide our comments as a part of the review of the partnership between research universities and the Federal government now being conducted by the President's Council of Advisors on Science and Technology (PCAST).

After considerable study of the topics of interest to PCAST, and because of our own interests and experiences, we have decided to share with PCAST our views on topic #8, "The Federal Government's role in expanding the number of university-based women and minorities in science and engineering."

Again, we thank you for this opportunity to give input with respect to this important area and you have our support as you examine these issues.

Sincerely,

William P. Hytche
President

WPH:ehb

cc: Ms. Bolek
Dr. Moore
Dr. Neufville



UNIVERSITY OF MARYLAND EASTERN SHORE
Princess Anne, MD

Response to:

President's Council of Advisors on Science and Technology

Topic:

The Federal Government's role in expanding the number of university-based women and minorities in science and engineering.

Response:

Although NSF and NIH, NASA, DOE, DOD and other Federal Agencies, Bureaus and Institutes have developed numerous funding mechanisms in this area of concern, the nature and scope of these mechanisms may result in the exclusion or non-participation of the intended audience.

The priorities, eligibility requirements, application procedures, response times, and restriction placed on the applicant tend to reduce enthusiasm for participation in many Federal research and research training grants and contract programs.

For example:

- Many supplemental grant award programs provide support for minority scholars willing or able to leave HBCU/MI institutions for training opportunities in majority institutions. Such actions can result in a talent drain from the very schools that are producing more than half of the minority college graduates in this country.
- Training grants typically address a narrow audience, i.e., college juniors or seniors, post-doctoral fellows or high school students. A college interested in providing a continuum of support is forced to prepare multiple applications responding to differing and often conflicting application criteria submitted to a variety of agencies with a 2% to 4% probability of receiving an award.
- Federal set-aside programs for HBCU/MIs frequently offer research opportunities that are irrelevant or insensitive, i.e., contracts for development of hi-tech military hardware or missile guidance systems. Knowledge of the history, mission and capabilities of HBCU/MI's would indicate that their strengths are in other areas of science and technology.

- Minority research grant programs, in general, tend to be segregated from the main stream of science and technology program administration in the Federal Sector, i.e., NIGMS supports Minority Biomedical Research Support (MBRS) Programs. The successful MBRS applicant interested in addressing etiological factors in cancer mortality and morbidity will not have their grant reviewed by the Cancer Control Review Committee and administered by the Division of Cancer Etiology. This means it will not come to the attention of NCI program officers, branch chiefs and division directors. Rather the grant will be separately reviewed and administered within NIGMS.*

*Although in many cases there is co-assignment of a subject matter expert in one of the NIH Institutes, these program staff have no official responsibilities and are almost always unknown to the grantees.

- The limited dollar amounts available combined with the instability of support from year to year make participation in many Federal efforts a risky business for the minority scientist.

Well intended as many efforts may be, current Federal grant and contract practices may be resulting in a reduction in the probability of HBCU/MI participation in research and research training efforts. One answer can be found in the block grant mechanism approach. Also, provision for an annual awarding of research training funds to HBCU/MIs could allow HBCU/MIs to reach parity with majority institutions.

"Document Control"

TYPE: ACTION DOCUMENT NUMBER: 9202509
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: BUECHNER, John C.: UNIVERSITY OF COLORADO AT DENVER

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/30/92

SUBJECT: HE IS FORWARDING HIS RESPONSE TO THE QUESTIONS PCAST
IS INVESTIGATING REGARDING THE HEALTH OF U.S.
UNIVERSITIES STUDY.

DIRECTORATE STAFF
ASSIGNED: PCAST ASSIGNED:

ACTION STAFF
REQUIRED: AS/IF NECESSARY ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 08/04/92 STAFF DUE DATE
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Chancellor's Office

Campus Box 168
P.O. Box 173364
Denver, Colorado 80217-3364
Phone: (303) 556-2643
Fax: (303) 556-2164

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92 JUN 21 10:21

OSTP
MAIL ROOM

June 30, 1992

Dr. D. Allan Bromley
Director of Office of Science and Technology Policy
Executive Office of the President
Washington, D.C. 20506

Dear Dr. Bromley:

Thank you for your kind letter, and for your invitation to respond to several questions the President's Council of Advisors in Science and Technology (PCAST) is attempting to resolve. I would be pleased to respond to some of your concerns as they hold great promise, as well as great challenges, for institutions such as the University of Colorado at Denver.

Initially, let me respond to the first topic on the PCAST list, as I believe my response here will touch on several other topics on the list. It is very difficult for institutions such as CU-Denver to fulfill its mission without the cooperation and support of the Federal Government. The monies provided for research projects and educational activities are essential to give our institutions the edge they require to become excellent universities. Yet, we find it very difficult to compete against the Harvard, Yale and Stanford's for these grant monies. Our faculty, although nonetheless creative, have heavier teaching responsibilities and cannot proceed as quickly towards an objective as can other faculty. We also often have university statutes providing a minimal teaching load that faculty are unable to buy out of. Nonetheless, we are a research university with valid, generally applied, research missions. We believe PCAST and the Federal Government could assist us by establishing funding requirements that force some Government funding for worthy projects suggested by our people.

The current climate for relations between our universities and the Federal Government is quite good. In general, we do not act to influence policy or to force funding into particular pockets. We, also, do not engage widely in pork-barrel opportunities to endow our campuses with Federal funds. We attempt to be cooperative and to engage in projects the Federal Government is sponsoring if they spark our creative juices. Thus, we are a cooperative partner. This relationship, however, is fragile and may not continue if the "major" research universities continue to absorb a differential share of the funding available.

The most pressing challenges confronting our types of research university in the next decade will be to maintain ourselves as viable research, and teaching universities. We are not like CU-Boulder and we must continue to assert that CU-Denver is a different type of equally necessary research university. We must seek local support for our efforts and attempt to focus our research agendas more directly on the applied problems confronting our local industries. We will need ongoing Federal support for this, and strong encouragement that this is the direction we should pursue.

Dr. D. Allan Bromley
Page Two

As a state university, I believe the Federal Government should never play more than an equal role with the state in providing us with the physical resources we require. Golly knows we need physical facilities, but we do not need the type of facilities needed by the major research universities. The state in which we reside should be the most interested in providing us with the proper facilities, and it is our job to convince them of this. No federal programs should be proposed to assist institutions such as CU-Denver, however, we would expect the Federal Government to be responsive should we call for a partial fraction of funding for a particular construction project (e.g., one that may be supported by Federal grants, etc).

We strongly support the merit-based per review system for supporting research. We only ask that reviewers be selected also from institutions like our own, so that the uniqueness of our situation may be presented.

Finally, we expect the Federal Government to continue its strong support to increase the university-based pool of health trained scientists and engineers and to continue its strong support of expanding the number of women and minorities selecting these professions. Without the financial support of the Federal Government, I believe we will be doomed to continue this fight forever, as we will never succeed without the funding provided to unique post-doctoral and women in science programs by the Government.

Thank you for giving us the opportunity to reply to your concerns. If you require clarification on any of the comments I have made, please do not hesitate to contact me.

Sincerely,

A handwritten signature in blue ink, reading "John C. Buechner". The signature is fluid and cursive, with the first name "John" and last name "Buechner" clearly legible.

John C. Buechner
Chancellor

"Document Control"

TYPE: ACTION

ORIGINATOR: 02

STATUS I

DOCUMENT NUMBER: 9202261

DIRECTORATE STATUS

FROM: DUNN, Mary Maples: SMITH COLLEGE

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/30/92

SUBJECT: SHE IS WRITING WITH HER COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE

STAFF

ASSIGNED: PCAST

ASSIGNED:

ACTION

STAFF

REQUIRED: AS NECESSARY

ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE: 08/20/92

STAFF DUE DATE

DATE COMPLETED:

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COPIES TO: D. Allan Bromley

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REMARKS:

PHONE:

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OSTP RECEIVED: 08/06/92

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Office of the President

2261
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Smith College
Northampton, Massachusetts 01063
(413) 585-2100 FAX (413) 585-2123

32 AUG 6 P 2:17

July 30, 1992

POST
MAIL ROOM

Mr. D. Allan Bromley
The Assistant to the President
for Science and Technology
The White House
Washington, D.C. 20500

Dear Mr. Bromley:

Thank you very much for your letter describing the work of the President's Council of Advisors on Science and Technology. Since it will not be possible for me to attend the public meetings you have scheduled, I accept with pleasure your invitation to send written comments.

I am sure you will hear from many of my colleagues, presidents of the "Oberlin Fifty" liberal arts colleges, asking you to remember that there are institutions which are not research-intensive, but which are instrumental in the training of young scientists. We believe that we are unusually productive in undergraduate teaching in science, and that the pool of potential scientists -- particularly of American scientists -- would be much weaker were it not for our work.

We have not had particularly strong support from the Federal government in the past, although we have appealed with some success for greater understanding of our contribution. I believe that this moment of reassessment of the relationship between the world of scientific education and the national government is the perfect time for scrutiny of our contribution, our needs, and the best place for us in the national partnership.

I am confident that the distinguished panel you have drawn together will not ignore the liberal arts colleges, and I am eager to be useful to your study in any way possible.

Sincerely yours,

Mary Maples Dunn

MMD/ng

cc: Harold Shapiro

"Document Control"

TYPE: ACTION

DOCUMENT NUMBER: 9202244

ORIGINATOR: 02

STATUS I

DIRECTORATE STATUS

FROM: COLE, Johnathan R.: COLUMBIA UNIVERSITY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 07/30/92

SUBJECT: HE IS FORWARDING HIS COMMENTS FOR THE PCAST PANEL
STUDYING THE RELATIONSHIP BETWEEN THE FEDERAL
GOVERNMENT AND RESEARCH INTENSIVE UNIVERSITIES.

DIRECTORATE

STAFF

ASSIGNED: PCAST

ASSIGNED:

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OSTP DUE DATE: 08/20/92

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2244

Columbia University
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July 30, 1992

Dr. D. Allan Bromley
The Assistant to the President
for Science and Technology
PCAST
744 Jackson Place N.W.
Washington, D.C. 20506

Dear Dr. Bromley:

I have enclosed a final version of the expanded written statement of my oral presentation. Although I was sorry I did not see you on Friday, July 24, I enjoyed meeting with the PCAST members and staff.

I look forward to the final report. Columbia is more than willing to assist in any way it can.

Sincerely,



Jonathan R. Cole

PRESENTATION

TO THE

PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

BY

JONATHAN R. COLE

PROVOST

COLUMBIA UNIVERSITY

**JULY 24, 1992
WASHINGTON, D.C.**

Dr. Shapiro, distinguished members of the President's Council of Advisors on Science and Technology and other colleagues, I am pleased to appear before you today on behalf of Columbia University. I am Quetelet Professor of Social Science, and for the past three years, I have been Provost of the University. My research has focused on the sociology of science, and, in particular, on the growth of knowledge, the peer review system and the treatment of women in science. From my current and previous angles of vision, I have observed first-hand the glory of the university-government partnership at research universities such as Columbia. In recent years, I have also unfortunately observed some of the strains. I am personally pleased that you have decided to review the roles played by research universities and the government in the research enterprise. At Columbia, we appreciate the partnership and offer some ways to improve upon it in the future.

My presentation will focus on continued investment in America's future. I will comment briefly on the history and promise of the partnership; on the consequences of that partnership for Columbia; on current threats to our historic relationship; and finally on some changes in the university and government roles that could result in still further distinction for American science and technology.

CONTINUED INVESTMENT IN AMERICA'S FUTURE: TRENDS AND GOALS

Over the past half century we have witnessed perhaps the most dramatic growth in scientific knowledge and technology since 17th century England. U.S. excellence in science and technology -- indeed U.S. preeminence over the past 50 years -- arose from an enlightened Federal policy that broadly supported research universities where the seeds of

knowledge were discovered, new technologies were conceived and incubated, and tremendous investment in human capital was made. The genius in the concept was in the nation's investment in the linkage between basic research and the training of new generations of scientists at America's colleges and universities. Much of the genesis of the current structure and success of the endeavors can be credited to the forward thinking of Vannevar Bush, Director of what was the first Office of Science and Technology Policy, and to his advisors. In his 1945 report, Science: The Endless Frontier, Bush wrote with great prescience:

...How do we increase scientific capital? 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. Second, we must strengthen the centers of basic research which are principally at the colleges, universities and research institutes. These institutions provide the environment which is most conducive to the creation of new scientific knowledge and least under pressure for immediate results. With some notable exceptions, most research in industry and government involves application of existing scientific knowledge of practical problems. It is only the colleges, universities and a few research institutes that devote most of their research efforts to expanding the frontiers of knowledge. (p.2)

Vannevar Bush's 1945 vision of the importance of linking research and educational training to the national interest led to the expansion of our national research enterprise, through the development of the National Science Foundation, the elevation of the National Institutes of Health and the development of permanent research programs in the mission agencies. With this system design, the U.S. embarked on a period of intense defense R & D and successful commercial technology development by private industry. The underpinnings of both ventures were the American university research and education system, a basic science enterprise unparalleled in human history. With the end of the cold war and with new technology-based economic competition, it is time to reconsider the design of the

American national system of innovation and the role of the university community in that system.

The design of the partnership between government and academia is the key public policy question in the new international competitive arena where science and technology dominate as the basis for that competition. Specifically, the key questions are:

- o If the university/government partnership is continued and improved, can universities contribute basic science crucial to advancing the United States as a supplier of high technology products to the world economy? Our share of this market has declined from 40 percent in 1980 to 37 percent in 1988.
- o If the partnership is improved, can enhanced Federal investments in basic research be used more effectively to stimulate growth and development in the U.S. economy? In certain areas, America maintains its competitiveness now, such as fiber-optics and drug discovery techniques, in other areas, such as memory chips, we have lost the competitive edge.
- o If the partnership is improved, can government investments in basic science and applied science at universities stimulate our world class scientists, engineers and managers to produce new inventions and discoveries?

o If the partnership is improved, can we continue to lead the international competition for scientific preeminence?

o If the partnership is improved and the federal government invests in national technology projects, can universities once again play a pivotal role in helping to secure national pre-eminence? In the past, our leadership was demonstrated through the development of radar, synthetic rubber and nuclear energy, among many other technology projects. Those types of national projects must be renewed.

THE CONSEQUENCES OF THE PARTNERSHIP AT COLUMBIA UNIVERSITY:

PAST AND CURRENT SUCCESSES AND EMERGING STRAINS

Columbia, which had established itself as one of the first American research universities before 1900, has worked in partnership with the Federal Government to serve the national interest since the 1940's. With the partnership as our base, we have attracted some of the 20th century's leading scholars to our faculty and future scientists to our student body. We count as Columbians over 40 of our current and former colleagues who have become Nobel Prize winners. Beginning as the first university participant in the Manhattan Project, Columbia has expanded its research base exponentially to include pathbreaking basic and applied scientific research that has benefited the American people directly. We have tried to be an exemplar of the partnership envisioned by Vannevar Bush and his colleagues. In addition, we have developed social science research to its highest order and feel strongly that it is a critical element of any national knowledge base.

We continue to serve the national science and technology enterprise through our commitment to pathfinding research, to the interplay between our undergraduate and graduate education, and to technology transfer and development. Like our sister institutions, we invest in a marketplace of ideas. Consider only a small sample of Columbia's contribution to the national welfare. In the biomedical sciences, "Columbia" discoveries include the first blood test for cancer, the first medical use of a laser, the first vaccine for RH factor, the first treatment for meningitis, and the first successful transfer of genes from one cell to another. In the geosciences, our projects on geochemistry, earthquake research, oceanographic research and non-renewable energy resources of all types have been recognized by panels of our peers for their ground-breaking discoveries. In fact, Columbia researchers were among the world's leaders in developing plate-tectonic theory, the unifying principles that allow humankind to understand the physical history and current restlessness of our globe.

In physics alone, 28 Nobel laureates have been a part of the Columbia research community during their careers, more Nobel prize winners than most other nations, including some of our key world competitors. For instance, Japan has received seven Nobel prizes since 1901.

Columbia's partnership with the Federal government has not only borne fruit in the physical and biological sciences but in the social sciences as well. For instance, Columbia

was the site of much of the original research on public opinion polling, on market research, and on American voting patterns.

Columbia invests a great deal in human capital. Many of our students will contribute to our future scientific base. The majority of our undergraduates attend graduate schools, many in programs of science and engineering. Columbia College alone has graduated more students who have gone on to win Nobel prizes than any other U.S. institution.

With the increasing stature and productivity of American university research has come an increase in the expectations from the public.¹ These rising expectations have emerged during a period of increasing financial constraints. We accept the challenges presented to us and are more than willing to be accountable for our research funds. At the same time, we know that methods of full-cost reimbursement or payment for the fair share of our costs must be found.

University technology transfer, one of the fruits of our basic science tradition, if measured by licensure and patents, has increased substantially since the enactment of "The Patent and Trademark Amendments of 1980." By giving universities stewardship of their

¹ A Congressional Office of Technology Assessment May 1991 report entitled Federally Funded Research: Decisions for a Decade notes that "The Nation now expects that in addition to knowledge, science and engineering will contribute to U.S. competitiveness here and abroad, create new centers of research excellence on a broad geographic basis, continue to provide unparalleled opportunities for education and training, and nurture a more diverse research force." (p. 3)

own intellectual property, the rate of licensing has increased. This has certainly been the case at Columbia. The technologies we have developed from our basic science discoveries range from pharmaceuticals and new materials to new exploration techniques for oil and new high-definition television. Some of the recently commercialized discoveries include:

1. COTRANSFORMATION PROCESS - a basic process used in biotechnology drugs. The process is used with two well-known drugs: (1) TPA (tissue plasminogen activator); (2) EPO (recombinant erythropoietin) -- a biotechnology product that stimulates the formation of red blood cells. This process was developed with basic science funding to researchers in the department of Microbiology and the Cancer Center.
2. MACROMODEL - a software system for studying the structure of complex chemical compounds with particular emphasis on a rational drug design. This package, which was developed in the Chemistry department, is widely used by the pharmaceutical industry.
3. SWITCAP2 - software used to design electronic circuits which convert analog to digital signals. These circuits are used in products such as pacemakers and cellular telephones. The software was developed by Columbia's Department of Electrical Engineering and is widely used in the electronic industry.
4. CYTO-DIFFERENTIATION COMPOUNDS - a synthesis of compounds that may act as differentiation agents in the transformation of cancer cells into normal cells. These compounds were synthesized by our Chemistry Department and are being tested in collaboration with Memorial Sloan Kettering and an industry sponsor.
5. JD SEIS - a seismic data interpretation software package that makes analysis of seismic information better and more efficient, and should lead to better identification of potential oil and gas deposits. This software was developed at Columbia's Lamont Doherty Geological Observatory.
6. TRANSVERSE ELECTROPHORESIS DEVICE - used as a laboratory tool to identify and characterize biological materials, it was developed by our Department of Human Genetics.

7. Development of cell lines used in commercial pregnancy test kits. The research was conducted by our Department of Medicine.
8. Development of an amino acid solution for use in pediatric nutrition. The research was conducted in the Department of Pediatrics.

These inventions, stemming from research at Columbia, indicate how crucial the investment in basic research is. None of these advances would have occurred if the federal government had not established a viable partnership with research universities like Columbia to advance the sciences.

Strains on the System

We join our colleagues from other institutions such as M.I.T. in reporting on the strains that have confronted us in recent years. In this current economy, with reductions in state and federal funds (particularly indirect costs), we have experienced particularly high levels of organizational stress. Let me highlight a number of problems that have contributed to the strain.

1. Strategic Dissonance in Research and Development

A key to the technological successes of the past 50 years and the dominance of U.S. science in general has been the strategic direction provided by the defense objective, the Apollo Program, the war on cancer and their national science and technology objectives. These national objectives were clear, and large segments of the science and technology community responded. Since the late 1970's, the U.S. strategy for science and technology

has lacked clarity resulting in poor development of national assets. The result has been a general focus away from the big question of how to maintain scientific preeminence and technological competitiveness in a changing world economy.

Universities, like other research organizations, need direction and purpose to be as effective as they can be. Such direction can only come from a well-developed set of national R & D objectives.

Without some planning and coordination at the national level, many universities are left with no choice but to strive for breadth and depth in nearly every subject. The result is a lack of concentrated excellence, lack of scientific focus and a generally inefficient research asset distribution system. Without some guidance and support, we are left with no choice but to compete on all fronts and potentially to overproduce graduate students. We need better definition and enhanced planning.

2. Federal Underfinancing of Research Costs

While Columbia has long supported changes to OMB circular A-21, recent modifications setting the administrative indirect cost rate arbitrarily at 26% will produce an annual loss of roughly \$7 million for Columbia. The loss of these funds, while seemingly small when compared to our large overall operating budget is, in fact, akin to the yield for annual use of a \$140 million endowment, or the resources that could support 70 professors

costing \$100,000 a year or about 230 graduate students at \$30,000 a year. In short, such arbitrary cuts at the margin have an enormous impact on the conduct of the scientific enterprise at Columbia. These losses have resulted in reductions in scientific jobs, reductions in the number of graduate students we train for Ph.D.'s., delays in needed maintenance, and reduction of administrative staff needed to support the research structure (including technology transfer). They have been real, hard-felt losses.

3. Graduate Student Education

Federally supported graduate student education at Columbia, as at other universities, is often not funded to cover the full cost of education. These gaps in costs must be compensated for by us from other revenue sources, including gifts, tuition, and the return on our financial aid endowments. Like other institutions, we support a large number of our graduate research assistants on grants and contracts. Their tuition is charged to our fringe benefits pool. Although only four universities currently use this method (Cal.Tech., M.I.T., Stanford and Columbia), it has worked well for us without added cost to the government. We see no need to change a system that has worked to the benefit of the nation since the Manhattan Project. The OMB/OSTP task force is currently examining this issue. Potential shifts in this policy could result in our inability to fund several hundred graduate students and would cause severe economic dislocations at Columbia.

4. Support for Scientific Buildings, Facilities, and Equipment

Expanded support for buildings, facilities and instrumentation is needed to maintain Columbia's excellence in scientific research. Increased support for the infrastructure of science could be obtained through facilities grants and interest free loans. Our borrowing is limited by an arbitrarily set not-for-profit bond cap of \$150 million. The university cannot presently recover from indirect costs the full cost of facility investments. Financial constraints within the University do not allow us to construct research buildings with general purpose funds.

5. Increasing Government Regulations

Expanded government regulation has produced added expenses across the board to meet health and safety requirements, to comply with important hazardous waste or red bag waste disposal, or to meet animal facility regulations. Meeting these regulatory requirements adds, of course, to the costs of research, but without additions to research support funds. At Columbia, our costs of implementation of the regulations exceed significantly our ability to finance them from the research enterprise.

**REFINEMENTS IN THE PARTNERSHIP:
UNIVERSITY AND GOVERNMENT ROLES**

The partnership between the federal government and universities involves, of course, mutual responsibilities. Universities have a responsibility to improve the way they conduct their part of the agreement. The academic community must be publicly accountable and do a better job of explaining clearly to the public how federal tax dollars are spent. More

importantly, universities need to develop means to enhance the rate of social and economic return on federal R & D investments. Such enhancements will require the university community to: 1) set basic science priorities, 2) establish and maintain merit review and peer review systems as required, 3) become more efficient in the use of resources, equipment and space. To do this, individual universities will need to plan and develop their research infrastructure more carefully and there will need to be more cooperation among universities involved in R & D activities.

In terms of financial management, universities if given full cost support for research, need to develop improved accounting and infrastructure investment practices. In improving our level of communication with the American public, universities ought to explain how the principle of full-cost funding is used to support research and train young scientific talent. Leaders of research universities must help strengthen the scientific voice, emphasize the importance of investment in science, and the social and economic benefits that are direct and indirect consequences of our work at universities. We must articulate the progress the scientific community is making on cancer detection and treatment, on prevention and treatment of AIDS, cardio-vascular disease, Alzheimers disease and diabetes, among others.

In terms of the government-university partnership, universities have a set of basic needs that merit consideration by the Council. Consider seven:

- 1. Universities need enhanced and targeted funding for graduate students. Such funding will require increased uncoupling of graduate student training support from**

the current grant system. Current shifts in overhead policy, increasing fringe benefit costs, and some agency reluctance to accept the high cost of graduate research education have provided disincentives for faculty to conduct their research with graduate students. Specific funding for graduate students should be provided in most basic science grants. However, we should increase significantly the number of training grants from NIH and NSF that can be focused on the training of our future scientists. When principal investigators must add the cost of training graduate students to their research grants, tension arises between their commitment to training and the cost and competitiveness of their grant proposals. This tension needs to be reduced and a new and improved student funding program would be very useful. It may be less expensive for scientists to hire technicians than to fund graduate students on their grants, or to maximize their published productivity by hiring post-doctoral rather than predoctoral students when the cost is roughly the same to the grant. This produces great fragility in the system, which is exacerbated when scientists lose grant support that is supporting graduate student training.

2. Development of consistent undergraduate funding to attract talented students to science and engineering, particularly women and minorities, and to provide undergraduates with appropriate opportunities for research. A critical factor in the choice of science as a career seems to be whether or not an individual worked on laboratory research as an undergraduate. Specific funding for this type of undergraduate experience is needed to attract more highly talented youngsters to

scientific careers. Columbia has initiated a number of small programs to facilitate interest in science. For example, the I.I. Rabi Scholars program is beginning its fourth year. The program has approximately ten undergraduate students per class and aims to recruit promising science students in an effort to involve them early on in active research. Special talks are given each year by distinguished scientists. Students write a research proposal, seek up to \$500.00 for equipment and books and are supported during the summers while they work on research projects. We need to expand these types of programs.

3. Stable, long-term support is needed for both research Center initiatives and investigator-initiated research. Research has become more expensive and complicated. Stable long-term research funding allows us to attract young new investigators and ease the burdens on our established investigators. Even our established investigators have expressed concerns about the amount of time they are spending applying for grants as opposed to doing research. Columbia's Center for Telecommunications Research, funded by the National Science Foundation, is an example of high-level cross-disciplinary research with funded projects pursued by teams. This center provides a platform for technology transfer and technological innovation. The center also involves industry and students at all levels. Present funding, however, places a ceiling of eleven years on support for the Center. Longer term support, tempered with rigorous external review, would allow time for additional discoveries and more technology transfer. In the NIH, growth in support

for basic research must be complimented by a renewed emphasis on clinical research to shorten the transition from the laboratory to the bedside in medical care.

4. Expand interdisciplinary research and development initiatives. Programs that create research incentives aimed at meeting critical national needs through interdisciplinary research should be expanded. For example, our Lamont-Doherty Geological Observatory and School of International and Public Affairs are spearheading an effort to develop a global environmental research and policy analysis program. The development of such efforts requires substantial institutional and core support that is generally not made available through individual investigator grants. By providing core funding, funding agencies should be encouraged to establish interdisciplinary research programs that link basic science and technology disciplines.

5. Develop improved and enhanced facilities programs at each mission agency and the NSF and NIH. It is quite impossible in the current economy of higher education for universities to finance and maintain scientific facilities under the current structure of Federal support for scientific research. Research universities simply cannot finance new state-of-the-art facilities from the funding provided through indirect cost recovery mechanisms. With those funds we can keep up with building maintenance but not with new demands for ever increasing high quality/high technology research spaces. To address this concern, we need the opportunity to make proposals to merit review panels for new facility and facility renovation funding.

6. **Remove the \$150 million cap on tax exempt bond financing to allow low-cost borrowing for facility development.** Private research universities cannot produce truly world-class research without adequate facilities. Uncapping tax-exempt financing for research facilities would level the playing field for private and public universities (the latter have no such cap). At Columbia, we have been forced to delay renovation of our Chandler chemistry and biomedical facilities because of the cost of borrowing funds. In each of the years from 1988 to 1991, Columbia borrowed 50 million dollars to meet current capital needs including renovations, construction of dormitories, off-campus housing and science laboratories. The funding was borrowed on a taxable basis. If one assumes a spread between taxable and nontaxable interest of approximately two per cent during that time, there is an increased cost per year of approximately one million dollars for each 50 million borrowed. If one compares the amortization of the debt over a 20 year period for each loan using the tax exempt bond rate versus the taxable issue, Columbia will have an increased interest cost of over 80 million dollars.

7. **Universities need simple, equitable and regionally appropriate indirect cost rates.** A recent study released in cooperation with OMB/OSTP by the Council on Government Relations (COGR) and the American Association of Universities (AAU) shows that indirect cost rate differences stem from **real differences in costs** rather than accounting differences. When revisions to Circular A-21 were published last fall, we noted that the 26 percent cap on administrative costs affected 75 percent

of private universities. Seven states (California, New York, Michigan, Pennsylvania, New Jersey, Connecticut and Illinois) absorbed 70 percent of the reduction. As I noted, this arbitrary reduction produced an annual loss of approximately \$7 million at Columbia, resulting in concomitant reductions in staff, delays of needed maintenance, and reductions in administrative support for research (including technology transfer).

Concluding Observations

I have reflected on a number of problems in the government-university partnership, all of which can be solved by a collaborative exchange of ideas. Your own committee's efforts represent an indicator of such useful discourse. At Columbia, we want to improve upon the existing partnership in ways that ensure continued scientific excellence for the nation. We need Federal support to reach that end - Federal support that recognizes that excellence is built upon adequate support for direct and indirect costs of research, facilities, and instrumentation. Our partnership has produced extraordinary scientific excellence, economic success and technology transfer for a half century. In an economy that is facing difficulties, universities can help to provide the base for future economic development.

Let me close with two final thoughts. First, it might be timely to revisit the idea of creating a cabinet-level office in the Executive branch for research and science policy development. The office would solidify the very important role played by OSTP and PCAST

and its members. Within this cabinet office, a university-research advisory group could be established to advise the federal government on academic science and technology policies. As science and technology becomes more complex, a coordinating agency may be needed to provide leadership, guidance and specific policies for enhanced research, productivity and national economic competitiveness.

Second, let us not forget that many sound ideas about the Government-University partnership were contained in the original 1986 Packard-Bromley report. As stated in the report's executive summary (p.3): "One conclusion is clear: our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support." As we examine methods of change, we should not ignore some tenets originally proposed in that report.

You will recall Isaac Newton's epigram: "If I have seen farther, it is by standing on the shoulders of giants." In this century, the partnership between the American people and universities, fostered by enlightened Federal support of university-based science, has led to the creation of giants. Many of us have seen farther because of this. We must not nibble away at fundamental structures of that partnership. It has, after all, enabled American society to become preeminent in science and technology. We are at risk of undermining it just when we must be strengthening it. Features of the support structure need to be changed and improved upon. We must work collaboratively toward that end.

Thank you for the opportunity to present some ideas to you. The project that PCAST is currently completing will have important effects on the future of research universities. Columbia University stands ready to assist you in any way that it can.